AUTOMOTIVE REPAIR

INSTRUCTION MANUAL OF REPAIR JOBS

VOL. I.

FOR THE

GENERAL REPAIRMAN AND THE OWNER

BY

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Director, Federal Board for Vocational Education;
Member Society Automotive Engineers.

SECOND EDITION

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AUTHOR'S PREFACE TO THE SECOND EDITION

THE revision of the manuscript and illustrations used in the original edition of this book was made by a committee of seven members of the staff of the Elm Vocational School, Buffalo, New York. The members of the committee were chosen because they were especially fitted, by experience and training in the field of automotive repair, to undertake this task, and because they had achieved success as teachers in this department of vocational education. The committee consisted of the following members:

William B. Kamprath, Principal; Martin H. Doebert, Acting Head, Department of Automobile Electrical Repair; Michael F. Steffen, Acting Head, Department of Automobile Mechanical Repair; Truman G. Dell, Instructor, Engine and Chassis Work; Alfred D. Neil, Instructor, Engine and Chassis Work; Guy Smith, Instructor, Automobile Machine Shop Work; Robert J. Marks, Instructor, Automobile Machine Shop Work.

In making the revision, the committee held frequent meetings for the purpose of considering, in joint session, what material should be added and what should be eliminated, in order that the revised text might be of the greatest value to both teacher and pupil.

As in the original edition, the emphasis has been placed upon repair jobs rather than upon theory of design or detailed types of construction. The repair operations and the accompanying text are all based upon a careful job analysis of the work the repairman must be able to do and the things he must know in order to be occupationally competent. This procedure is becoming more and more generally recognized, in recent years, as the best one to follow when preparing text material.

The author again expresses his appreciation to the many individuals and concerns that so generously assisted in the preparation of the original manuscript, to the members of the committee of seven making the revision, and to many manufacturing firms for permission to use cuts, drawings, and instructional notes taken from their catalogs and instruction manuals.

J. C. WRIGHT.

INTRODUCTION

The elimination of "guess work" in the repair and operation of automotive equipment can only be accomplished through a *systematic study of the conditions which cause "trouble"* supplemented by an extensive practical experience in the elimination of these conditions.

By far the largest number of repair jobs which come to a repair shop are of a general character. They become the responsibility of the general repairman and not of the special service man. To be a good electrical service man one must understand a great deal more about the theory of electricity than is necessary for the general repairman.

The entire subject matter has, therefore, been selected with the definite aim to meet the need of the man who is expected to make general repairs and to keep the car fit for operation. The student may be a repairman or the owner.

Jobs clearly of a service nature have been omitted from the text in order to keep the contents lined up with the duties of the general repairman.

Additional texts have been prepared for use of Electrical Service Men, Battery Service Men, and Tire Service Men. In these manuscripts the additional jobs in automotive repair which require special treatment and advanced technical knowledge are included.

The mechanical and electrical equipment used on automobiles of to-day is too complex to be understood without special study. *This book is intended for the instruction of the repairman or the car owner and may be used in an Automotive School or class or in home study and self-improvement.*

The element of "guess work" has been further eliminated by an analysis of the trade as a means of selecting the repair jobs and by including in the subject matter information relating to the theory of gas engines. The analysis was made in cooperation with men who had had years of experience in repair work and who were practiced instructors in automotive subjects. Every one of the 121 jobs was carefully considered and finally selected because of the fact that it represented the kind of work which is daily brought to the repair shop.

The theory of gas-engine mechanics is limited to such studies as

may be helpful in understanding the repair jobs and in diagnosing the conditions accompanying the unusual job.

The subject matter is arranged so as to present the jobs in Part One by chapters covering chassis, engine, electrical, trouble shooting, and body and radiator work, and the theory in Part Two by subjects including the chassis and its construction, automotive engines, lubrication, applied electricity, ignition, starting and lighting, engine fuels, carburetors, cooling systems and tire work.

When the text is used in a classroom, lessons may be assigned from Part One and Part Two simultaneously. That is, the jobs may be taken up either on the equipment in the shop or on productive repair work which comes in from the outside. The references to Part Two should be studied in connection with the lessons on that particular job given in Part One.

The jobs are arranged in an instructional order if given from the shop equipment. Where outside work is brought in they may be taken up in advance of the suggested order without doing any serious harm to the course.

When the book is used by owners a car of any make should be available to serve as equipment for the better understanding of the subject.

It is obvious that the operations and descriptions of operations could have been carried to such a degree of detail that the mere reading would become monotonous and detract from the value of the book. No claim is made to an exhaustive treatise of every possible repair job nor to a consideration of all models or types. Books which attempt to include specifications for all models and makes soon become an encyclopedia of little use to those for whom this book is intended.

When specific adjustments are to be made on any car with which the repairman is not familiar, the manufacturer's instruction book should be consulted. Different instructions are frequently given in these books for the adjustment of spark plugs, valve clearance, and for ignition breaker points. The adjustment of carburetors and layout of electrical wiring diagrams are also typical of the wide variation in specifications and construction.

A thorough training in and understanding of the repair work included in this book will furnish a practical experience covering at least 95 per cent of all the problems with which the general repairman or owner who takes care of his own car may be confronted. The technical information contained in Part Two is more than sufficient to enable the students to understand the operation of gas engines from a theoretical standpoint.

AN APPRECIATION

By Dr. C. A. Prosser,
Director, Dunwoody Institute,
Minneapolis, Minn.

It gives me a great deal of pleasure to make this statement concerning Mr. Wright's book on Automotive Repair.

My long acquaintanceship with the author led me to expect much from him when he set himself, in the press of administrative duties, to prepare a thorough-going treatise on the repair of automobiles. He combines with a great deal of practical and executive experience in a number of vocations, including automotive repair, a rare ability to analyze conditions and needs and to organize material to meet them.

It was to be expected that anything coming from the author would be based on a close analysis of the principal repair jobs to be encountered, of the operations necessary to meet them, and of the steps to be taken in the performance of each job involved. No other text which I have seen as yet has done this so consistently and fully as have the several volumes in this series

Brevity is always a virtue and it is found in this text to a rare degree. There are no unnecessary discussions and no padding with unnecessary material. The information necessary for the student to proceed intelligently with his task is given in brief attractive form as a part of the description of the operations necessary to be performed. This is creating the apperceptive basis in the right way.

In this way theory is never abstract and discursive, but always applied and direct.

In this respect this text sets a model by which others who are writing in the field, preparing text books for use by students in vocational training, can profit to advantage.

In the organization of his material for instruction purposes this book follows the four steps so clearly set forth by C. R. Allen, which are coming to be universally recognized as sound and effective in all vocational teaching:

Preparation of the student for the new work is gained at the outset of each new job lesson through references to other parts of the book which call up to the mind of the student previous work performed as a background for the new work, or reading to be done bearing on the new task.

Presentation is gained by throwing up into the foreground an analysis of the operations necessary to perform the job and a description of the things to be done.

Application is secured through the performance of the task under the directions given for the task; and the *student is tested* through the questions that follow at the close of each job treatment.

I predict that this book will have a wide sale for use in schools and that it will be closely studied with a great deal of interest by those interested in the development of effective text-book material for use in trade and industrial education throughout the country.

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PART ONE

INSTRUCTION MANUAL OF REPAIR JOBS

AUTOMOTIVE REPAIR

CHAPTER I

CHASSIS WORK

Job No. 1

REPAIRING BENT AND BROKEN FRAMES

References.—Part Two, p. 343.

Operations Necessary to Perform the Job.

1. Remove body and engine and other parts as necessary.
2. Inspect the frame for all defects in alignment and assembly.
3. Straighten side or cross members, cold or hot, depending upon the nature of the bend.
4. Remove defective rivets and replace with new rivets.
5. Rivet or bolt patch on broken member (if necessary, have parts welded).
6. Replace new side or cross members or other parts as necessary.
7. Square and true up the frame or install a new frame.
8. Paint all parts as needed.

Names of Materials, Tools, Parts and Operations to be Reviewed before Performing the Job.

Material.—Iron rivets, steel plate or channel, iron paint, bolts and nuts.

Tools.—Hoist, wrench, cotter key puller, rivet buster, punch, hammer, blocks, gas torch, chain, screw jack, sledge, chisel, rivet set, forge, counter sink, drills, brace, steel tape, taps and dies both U. S. and S. A. E. Standard, arbor press, bench vise, grinder, and welding outfit.

Parts.[1]—Frame side member, front cross member, rear cross member, center cross member. First cross member, second cross member, sub-frame side member, sub-frame cross member, gusset.

[1] Nomenclature, by permission of the Society of Automotive Engineers.

Fig. 1*b* could be used to advantage for school purposes. One of these kits can be assigned to each student; he can be made responsible for the condition of the tools and box. Each day the kit may be given out at the beginning of the instruction period and returned to the tool crib at the end of the period. This kit is constructed of wood and contains the following tools:

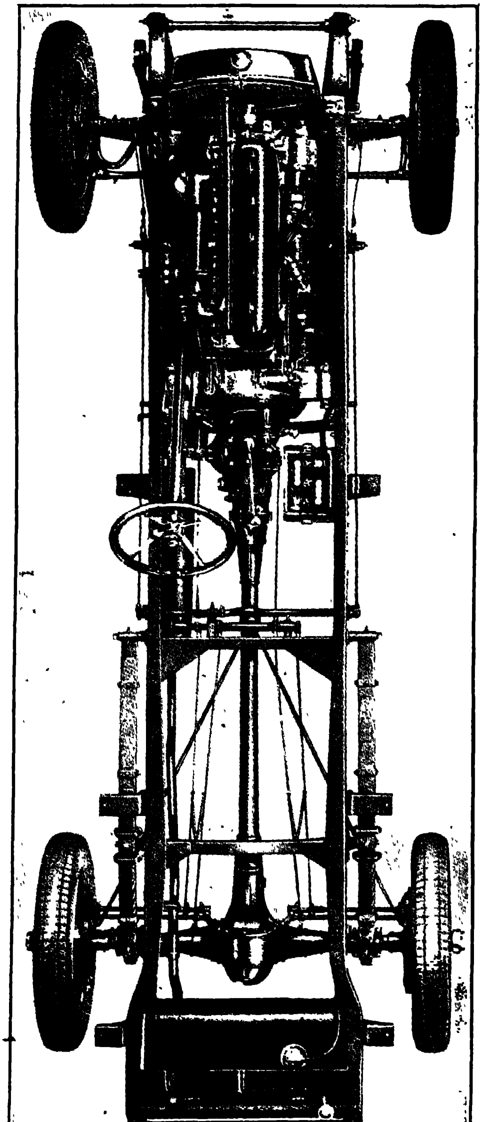


Fig 1c.—Plan of Chassis.

1 $\frac{3}{4}$ lb. Hammer
1 8″ Screw Driver
1 Pair 6″ Combination Pliers.
1 2″ Screw Driver
1 Set of End Wrenches Nos. 23 to 31, inclusive.
1 10″ Flat Mill File
1 8″ Drift
1 10″ Crescent Wrench
1 6″ Crescent Wrench
1 Cotter Puller
1 6″ Steel Scale.

Safety First.—When the body is to be blocked up or removed, care should be taken, through the use of safe and stable blocking to prevent injury to workmen and others. Hoists and chains sometimes slip and not only cause injury to the workman but also damage to the repair work.

It pays to take a few extra minutes in seeing that everything is ready before beginning to disassemble and to remove parts.

Description of Operations.

In straightening a bent frame the repairman should remove such parts as will enable him to have free access to the damaged member. After he has determined the location of the bend he should apply a straightening device, which usually consists of a screw jack, a suitable chain, and a block of wood. If the bend cannot be removed without heating the member a torch should be applied and the flame directed

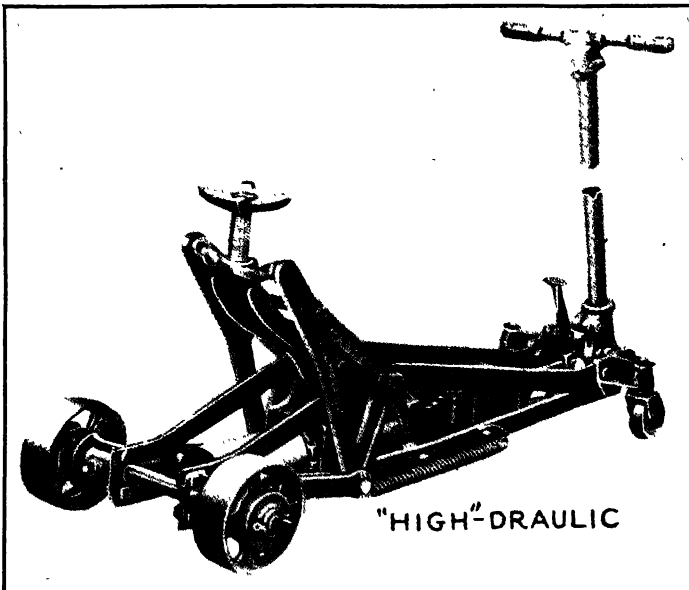


FIG. 1*d*.—Modern Hydraulic Jack.

upon the damaged part, at the same time applying pressure until the bent member is forced back to its normal position. During this process a hammer of sufficient size should be used for straightening out short kinks.

When rivets are to be removed use a sledge or old axle shaft for backing up while cutting off the head with a sharp chisel. After all the defective rivets have been removed, the holes should be inspected and if they are found to be " out of round " they should be reamed and chamfered. The members of the frame should be lined up and the parts to be riveted firmly clamped together, care being taken to see that the rivet holes are in line. Rivets of correct size and length are next selected and placed in a forge. When heated to a deep red, the rivet should be

inserted in the hole and a sledge or other suitable tool placed against the rivet head for backing up. A hammer should be used for the purpose of stoving and swelling the rivet to a tight fit in the hole. While the iron is still hot finish the head with a rivet set.

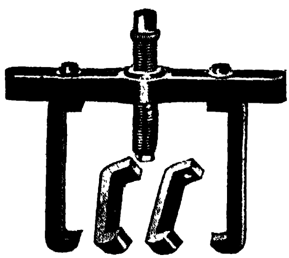


FIG. 1*e*.—Wheel and Gear Pullers.

If a weld has been made a patch should not be placed over the welded part.

When replacing new side or cross members, remove the old member as noted above and install the new part.

When squaring up a frame it is necessary to determine the amount the frame is out of line. To do this measurements should be made diagonally from the rear cross member to the front cross member (distances *A* and *B* in Fig. 1*g*). Next locate the center of the front and rear cross members (*E* and *F* and *C* and *D*). A line should then be stretched from the center of the rear cross member to the center of the front cross member and measurements made from this center line to the side members. A straightedge may then be used to locate twists in the side members.

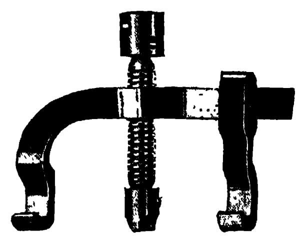


FIG. 1*f*.—Tallman Straight-

A sagging side member can be restored to its normal position by the use of iron truss rods. A truss-rod hanger is riveted to the side member in front of the sag and another is placed behind the sag. "Eyes" are then formed at the ends of the rod so it can be attached to the truss-rod hangers. A turn-

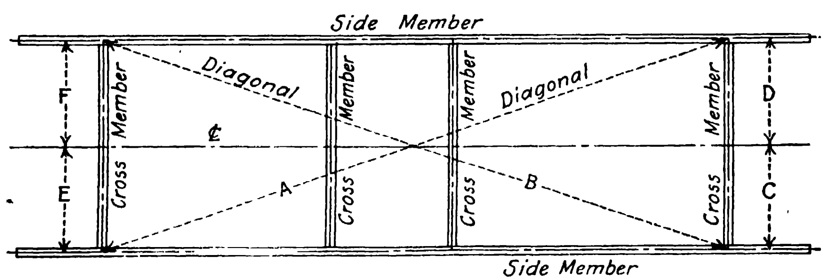


FIG. 1*g*.—Plan of Frame Showing Measurements for "Truing Up."

buckle should be placed about one-fourth of the rod's length from the end. Now place a block of wood between the truss rod and the under

side of the sagged part of the side member and by tightening the turn buckle force the member back to its normal position.

After the frame has been repaired, all damaged parts should be painted in order to protect them from the weather and to leave a good finish.

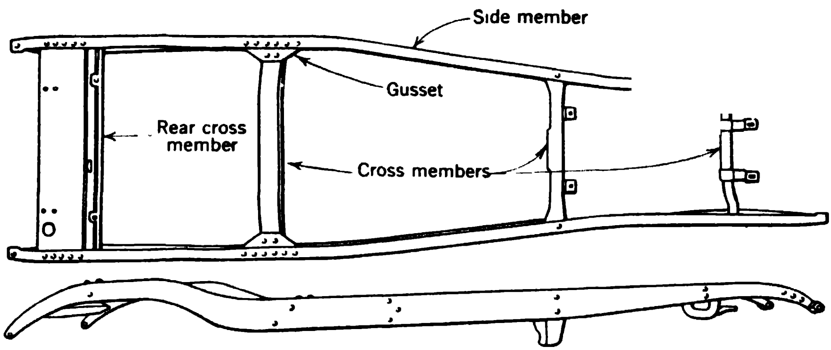


FIG. 1h.—Top and side View of Frame.

Questions.

1. What are the names of the different parts of the frame?
2. How are these parts held together?
3. What is an indication of looseness at the joints?
4. Why is riveting better than bolting to hold the parts of the frame together?
5. Are the rivets driven hot or cold?
6. Is the material in a frame brittle?
7. Would it be easy to drill?
8. If a bracket is loose, does it pay to attempt to tighten the old rivets?
9. When new rivets are to be driven, what should be done to the holes?
10. What should be used for backing up a rivet when it is driven?
11. Would a light or a heavy hammer be better for driving a hot rivet? Why?

JOB No. 2

REPAIRING OLD SPRINGS AND INSTALLING NEW SPRINGS

References.—Part Two, p. 347-8:

Operations Necessary to Perform the Job.

1. Block up body.
2. Remove rebound clips.
3. Remove shock-absorber equipment.

4. Detach springs from frame and axle.
5. Remove tie bolt.
6. Inspect leaves for breaks or cracks.
7. Inspect for lack of pitch and worn bushings.
8. Install new leaves, new bushings, new bolts, or complete new springs.
9. Ream new bushings.
10. Clean oil passages in bolts.
11. Reassemble all parts of the spring and attach to frame and axle.
12. Inspect rebound clips and retaining clips or "U" bolts to see if properly adjusted.
13. Inspect shock absorbers, repair if necessary, and replace.
14. Lubricate the shackle bolts.
15. Clean spring.
16. Remove blocking.

Names of Materials, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Materials.—Kerosene, lubricating oil, cup grease, new springs or leaves, spring bolts, bushings.

Tools.—Expansion reamers, tool-roll or tool-kit equipment, jacks, blocks.

Parts.—Frame brackets and sockets—front-spring front bracket, front-spring rear bracket, rear-spring front bracket, rear-spring rear bracket, running-board bracket, running-board bracket brace, engine front support bracket, engine rear support bracket, torque-arm bracket, radius-rod bracket, cross members, sub-frames.

Front Springs.—Front-spring shackle, front-spring shackle bolt, front-spring front bolt, front-spring rebound-clip, front-spring seat, front-spring seat pad, front-spring clip, front-spring clip plate, front-spring center-bolt.

Rear Springs.—Rear-spring pivot bolt (or pin) (for half-elliptic cantilever spring), rear-spring pivot seat (for half-elliptic cantilever spring), rear-spring double shackle (for platform spring), rear side spring (for platform spring), and cross spring (for platform spring).

Operations.—Fitting new leaves, fitting bushings and shackle bolts.

Special.—" Archer Set."

Description of Operations.

Whenever a repair job comes into the shop the repairman will save a great deal of time and unnecessary floor travel by looking the repair job over for the purpose of determining what must be done and what parts should or should not be removed in order to do the job. Time

will also be saved by selecting the right tools and by procuring the material necessary to complete the job.

When a job involving front axle spring work comes into the repair shop it is usually found necessary, after an inspection of the car, to block up the frame so that the spring clip (Fig. 2*a*) may be removed, that the shackle bolt (Fig. 2*b*) and spring eye bolt, as well as the spring retaining clips (Fig. 2*a*), may be removed in order to detach the spring from the axle. With the aid of a vise or a " C " clamp, the leaves can be compressed while the tie bolt is being removed. After releasing the springs the leaves should be cleaned with kerosene and inspected for all defects such as breaks, cracks, worn bushings, or lack of pitch. If a leaf is found to have lost its pitch or to be broken, the repairman should replace it with a new leaf. (Do not attempt to weld or reset the defective leaf.) If the bushings in the end of the spring are worn they should be replaced. Care should be taken to see that new bushings are not damaged in installation. The bushings should be inserted by using a lead mallet, wooden block, or some other soft material suitable for the purpose. After inserting a bushing the repairman will usually find that the spring eye and shackle bolts fit too snug. This can be overcome by reaming the bushing to the correct size. The leaves should then be cleaned by removing all rust and scales with emery cloth.

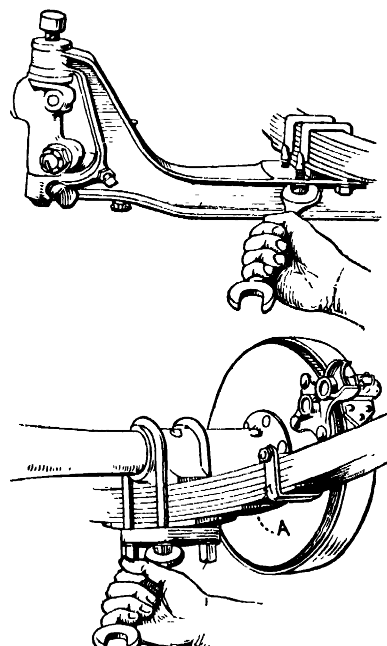


FIG. 2*a*.—Tightening Spring Clips.

To reassemble, compress the spring leaves in a vise or a " C " clamp. At the same time a small rod should be used to line up the spring center holes. As soon as the springs are compressed the rod is removed and the old tie bolt, if in good condition, is replaced. Always make sure that the tie-bolt head is on the proper side of the spring. The next step is to replace the rebound clips and the shackle bolts, again making sure that the oil passages are clean in the bolts, and attach the spring to the frame.

The job is now finished by replacing the retaining clips, attaching the spring to the front axle, and inspecting the axle for alignment.

One of the most annoying rattles about a car is caused by side play at the spring ends in the shackles.

The direct cause of this looseness is natural wear or lack of lubrication. Driving over muddy roads, and then allowing the car to stand without proper attention to these shackles, permits the mud to work into the shackle bolts, creating a condition which naturally brings about this result much more quickly than normal wear would do.

Lubricating the spring shackle bolts every 500 miles will insure the maximum life of these parts; and an owner may be sure that unless he follows instructions in this respect the excessive wear on the bushings will call for replacement of the parts within a very short mileage.

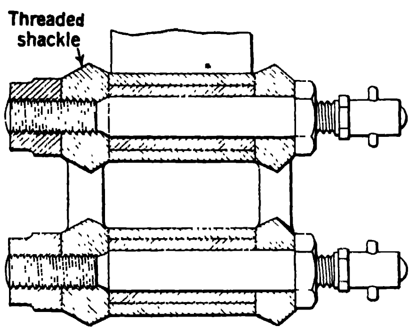


FIG. 2b.—Rear Shackle Bolt Adjustment.

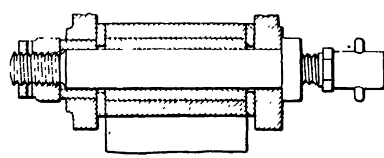


FIG. 2c.—Front Shackle Bolt Adjustment.

Spring shackles are exposed to the mud and dirt from the road, and unless the lubricant is forced from the interior outward, so as to carry with it all particles of grit, it is obvious that the dirt will work into the bushings and destroy them in a very short time.

Those having the responsibility for the care of automobiles should keep the following points in mind in order to avoid trouble:

1. Always keep the spring retaining clips tight, for spring breakage is invariably due to spring clips being loose and to their failure to hold the spring firmly to its seat.

2. After the car has been driven a few hundred miles there is a tendency for the retaining clips to loosen, and for this reason the spring clips should be tightened as often as found necessary.

Questions.

1. Where is the front spring most likely to break?
2. What effect will the tightness of the spring retaining clips have upon the liability to breakage at this point? Why?

3. What provision is made to prevent the leaves from pulling apart when the vehicle rebounds?
4. After several months' use, in what condition will the leaves of a spring be found?
5. Will this have any effect upon their flexibility?
6. Is there any motion of one leaf against the other when the springs are deflected?
7. Should the retaining clips be loosened before or after the weight of the frame has been lifted with the jack?
8. If the spring clips are allowed to remain loose, what will happen to the center bolt?
9. If the leaves of a spring are allowed to separate, how can they be reassembled with a short center bolt?
10. What materials are used for spring eye bushings?
11. Of what material is the pin made so that it will not wear rapidly?
12. If oiling or greasing has been long neglected, in what condition will the drilled passages be?
13. If the bushing is made of bronze, what must be done to the hole to make it fit the pin?

Job No. 3

STRAIGHTENING A BENT FRONT AXLE

References.—Part Two, p. 352.

Operations Necessary to Perform the Job.

1. Block up frame of chassis.
2. Remove wheels.
3. Remove spindles and knuckles.
4. Remove spring retaining clips.
5. Straighten axle if equipped to do so; use "cold method" if possible and "hot method" when necessary, depending on nature of bend or size of axle. If the shop is not equipped to straighten an axle, the job should be sent to a shop that is so equipped.
6. Check the axle for bends, backward or forward, up or down, between and outside of spring seats, and check for twists between and outside spring seats.
7. Replace the axle and check for adjustment with rear axle.
8. Lubricate and reassemble front system.
9. Align front wheels.

Names of Materials, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Tools.—Anvil, jacks, blocks, square, 5 lb. sledge hammer, heating

device, wheel aligning fixture, bending bar, " Tee " square, straightedge, and straight rods.

Parts.—Front axle, front-axle yoke, front-spring seats, front-axle bushing.

Description of Operations.

When a front axle has been bent the repairman will find it necessary either to straighten the axle himself or to have it straightened by a shop which makes a specialty of straightening automobile parts.

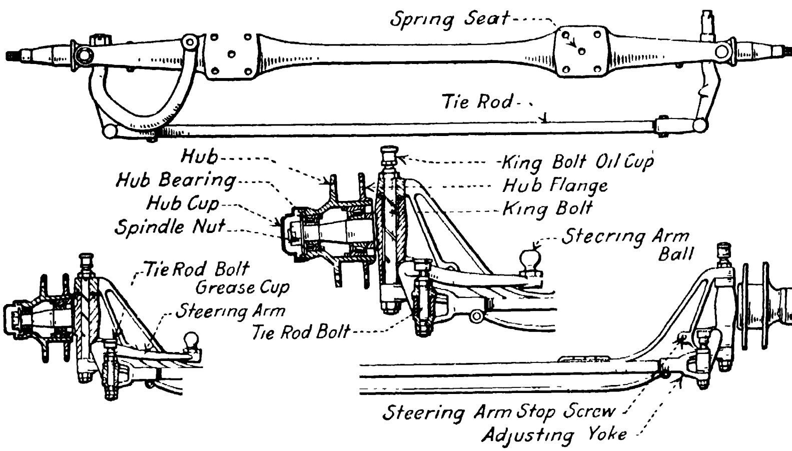


FIG. 3*a*.—Front Axle.

To repair the axle, block up the front of the car as described in Job No. 2 and remove the knuckle assembly, the wheels, and the tie rod. The spring retaining clips can then be removed and the front axle (Fig. 3*a*) taken out and checked for all possible bends and twists.

A line reaching from the center of holes $A-A$ in Fig. 3*b* should pass through the center of the axle for its entire length and any variation

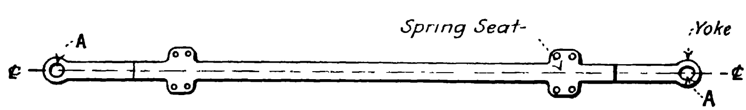


FIG. 3*b*.—Plan of Front Axle.

indicates that the axle has a bend either forward or backward. In Fig. 3*c* a straightedge is placed across the spring seats $A-A$; if no bend " up or down " exists between the spring seats, the straightedge will coincide with the surfaces of both seats.

When the spring seats are parallel, rods having a diameter equal to that of the holes in the axle yokes and about 3 feet in length should

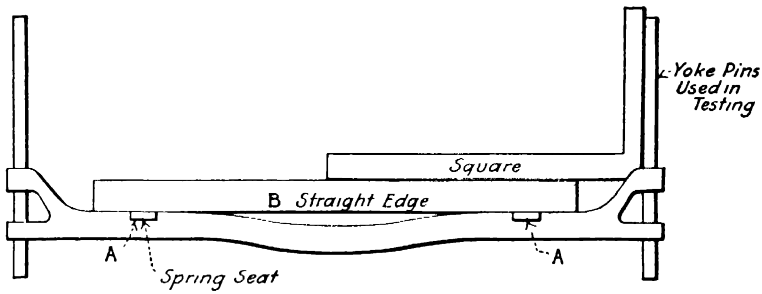


Fig. 3c.—Front Elevation of Front Axle Showing Method of Checking Front Axle for Vertical Bends.

be inserted as in Fig. 3c and a carpenter's square placed on the straight-edge resting on the spring seats may be used to check the axle for "up and down" bends outside of the spring seats.

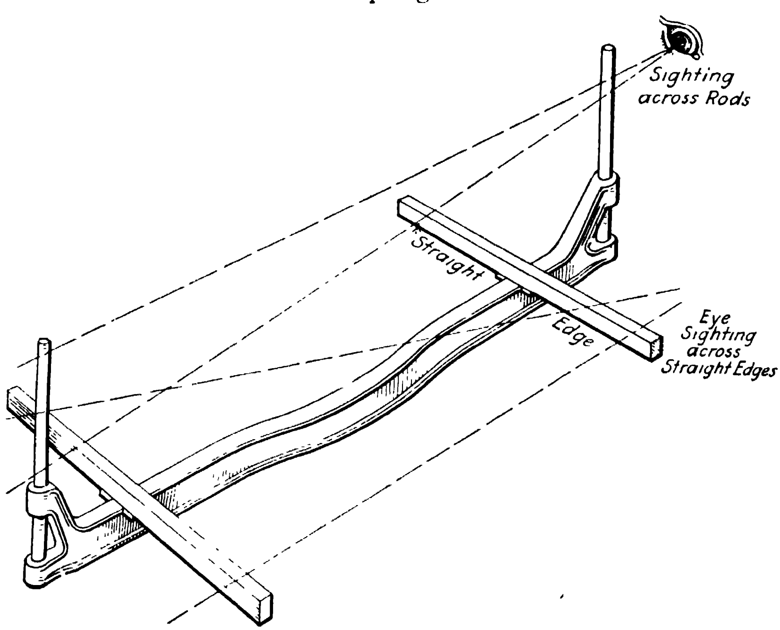


Fig. 3d.—Checking Front Axle for a Twist between Spring Seats and Outside of Spring Seats.

Figure 3b shows a straightedge on each of the spring seats placed at right angles to the axle. Sighting across the edges, the repairman can

readily determine whether the axle has a twist between the spring seats.

If the repairman is satisfied that no twist exists between the spring seats, a rod should be placed in each end of the axle yoke as shown in Fig. 3*d*; if these rods are not parallel a twist will be found in the axle outside of the spring seats.

When the bend has been located, straighten the axle cold, if possible. If this cannot be done, heat the axle at the bend and, by the use of a sledge and anvil or a press of sufficient size, force the axle back to its normal position.

Should the axle have a twist in it the part should be heated at the twist and then placed in a vise. A rod placed through the axle yoke may be used as a lever for twisting the axle back to its normal position. The axle should then be painted, attached to the springs, and lined up with the rear axle and frame as described in Job No. 1. The front wheels and steering mechanism should now be replaced and the blocking removed.

Difficulty in steering and excessive wear on the front wheel tires are sometimes caused by an improper setting of the front wheels, the result possibly of an accident, and attention is called to the fact that the front wheels have a gather, or are "toed" inward at the front from $\frac{1}{4}$ to $\frac{3}{8}$ inch. This measurement should be taken front and rear at the felloe band, and in a horizontal plane passing through the center of the wheels. An adjustment can be made, if necessary, by means of the adjustable yoke on the tie rod between the steering knuckle arms. (See Job. No. 8.)

Questions.

1. When a twist is located how can it be removed?
2. What are the tools which should be used in straightening a front axle?
3. In Fig. 3*d* how can you determine whether the twist is between the spring seats or between the seat and yoke?
4. In Fig. 3*d* how can you check the axle for backward or forward bends?
5. Which is the better practice, to straighten an axle cold or to heat it? Why?
6. What is meant by "caster" and how can it be restored after straightening an axle?
7. Determine by measurements the "caster" and "toe in" which have been given to several of the cars in your shop.
8. Name all of the parts of the front axle.
9. Why are front wheels set closer at the bottom than at the top? (See Job No. 8.)
10. Why are they set closer at the front than at the back? (See Job. No. 8.)

Job No. 4

REPLACING BROKEN OR BENT KNUCKLES

References.—Part Two, p. 343.

Operations Necessary to Perform the Job.

1. Block up car.
2. Remove wheels.
3. Remove broken or damaged part.
4. Replace part.
5. Replace and lubricate steering-knuckle pin.
6. Lubricate bearing.
7. Make bearing adjustment.
8. Lock bearing adjustments.
9. Pack hub cap with grease.
10. Replace hub cap.
11. Clean and lubricate tie-rod pivot pin and replace.
12. Lock nut on tie-rod pivot pin and remove blocking.
13. Align wheels.

Description of Operations.

The wheels can be removed from the front axle by taking off the hub cap and the nut and washer on the end of the steering-knuckle. Tapping the hub of the wheel outward will release the bearings so that the wheel can be pulled off the steering-knuckle.

On most cars the steering-knuckles can be removed from the axle by taking off the nuts at the bottom of the pivot pins and unscrewing the pins. (Fig. 4*a*.) The knuckle may then be removed from the axle yoke.

Thoroughly clean all parts by washing them in a pan of kerosene.

There are two adjustments in connection with the front axle, namely, the wheel bearings and on some cars the steering-knuckle anti-friction bearing.

Should play develop between the steering-knuckle and the axle yoke, it may be taken up by installing spacers or replacing bushings. The knuckle should be tightened just enough to remove the play and not enough to bind the bearing. With the adjustment made, the lock nut should be replaced on the bottom of the pin and locked with a cotter key or other locking device.

In reassembling the wheels on the steering-knuckles or in taking up play, the wheel bearings should be carefully cleaned and inspected.

Examine felt washer, pack hub with grease, and mount wheel on the spindle with the bearings in place. The washer and nut should then be mounted on the end of the steering-knuckle. The wheels should then be rotated by hand while the nut is drawn up until the wheel binds. Now turn the nut back until the cotter-pin hole in the spindle registers with the next slot in the nut. Rap the wheel outward to free the bearings and see if the wheel spins freely. When the adjustment is

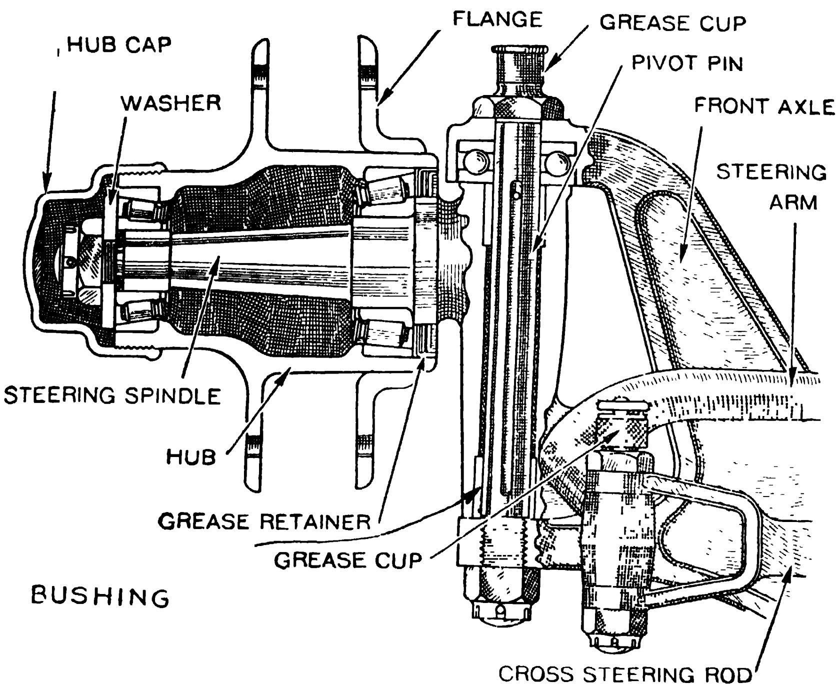
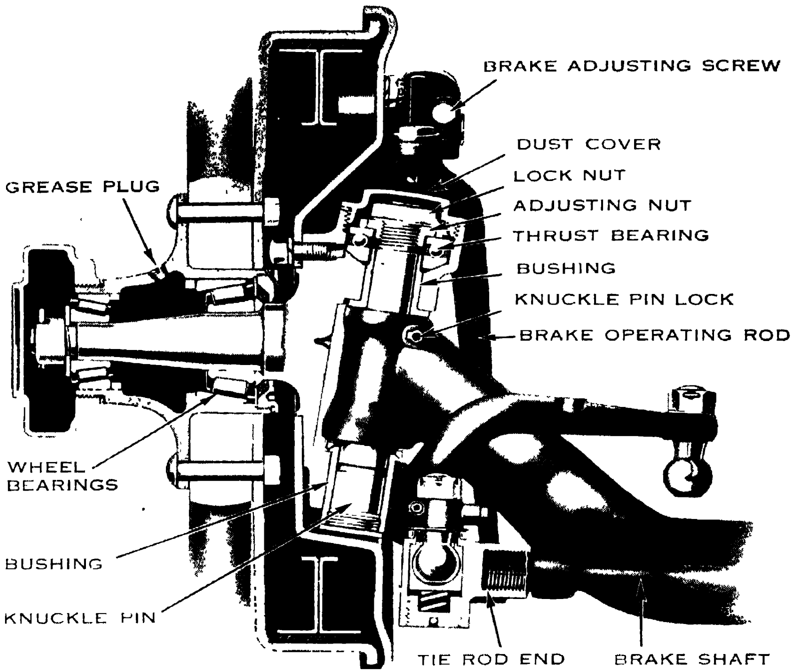


FIG. 4a.—Section through Hub and Knuckle.

satisfactory lock the nut in place with a cotter key. The correct adjustment has been made when the wheel revolves freely with just a perceptible shake in the bearings. Grease should then be packed inside the hub cap and the cap replaced.

Questions.

1. What is a good test in making a front-wheel bearing adjustment?
2. How may the amount of play in steering-knuckles be determined?
3. What materials are commonly used in making knuckle bushings?
4. How are knuckle bearings lubricated?



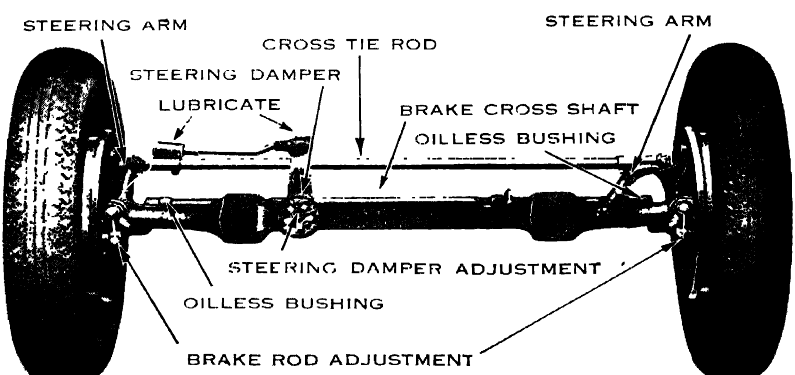


FIG. 4*b*.—" Reversed Elliott " Steering Knuckle (Marmon).

5. How are inner cones installed?
6. How are the bearing balls and rollers retained in the race?
7. How should a front wheel be removed?
8. How are knuckle bushings fitted to the pivot bolt?
9. What tests for wheel alignment should be made before the job is completed?

Job No. 5

REBUSHING STEERING KNUCKLE

References.— Part Two, pp. 343, 352.

Operations Necessary to Perform the Job.

1. Block up body.
2. Remove wheel.
3. Remove knuckle from axle.
4. Clean all parts.
5. Replace spindle if bent.
6. Replace knuckle bushings.
7. Ream bushings to fit knuckle pin if necessary.
8. Fit knuckle to axle yoke.
9. Assemble knuckle assembly.
10. Replace wheel and complete job as for replacing broken knuckles.

Names of Parts to be Reviewed before Performing the Job.

Steering-knuckles.—Right steering-knuckle, left steering-knuckle, steering-knuckle bushing (upper and lower), steering-knuckle pivot, steering-knuckle-pivot nut, steering-knuckle thrust-bearing, right steering-knuckle arm, left steering-knuckle arm, and steering-knuckle gear rod arm.

Steering-rods.—Steering-knuckle tie rod, steering-knuckle tie-rod clevis, steering-knuckle tie-rod clamp bolt, steering-knuckle tie-rod pin, steering-gear, and drag link.

Description of Operations.

When a knuckle assembly needs rebushing, the knuckle should be removed according to previous instructions. If the bushings are found to be worn, they should be punched out and new bushings installed. The new bushings must be fitted to the knuckle and to the pivot pin. (Fig. 4*a*.) In case the spindle is bent, thereby destroying the camber of the wheels, the spindle should be replaced with a new part. After

the repairs have been made, the job is finished according to instructions given for Job No. 4.

Questions.

1. What tools should be used to remove and install knuckle bushings?
2. What tool is used in fitting the new bushing?
3. How can you determine whether a spindle is bent?
4. Why is it unsafe to straighten a bent spindle?
5. When pivot pins become stuck because of lack of lubrication, how should they be removed?
6. How often should front wheels be lubricated?
7. What kind of lubricant should be used for the bearings of the knuckle assembly?
8. If a race or cone is a snug fit on a spindle, what precautions should be taken in removing it?
9. If it is driven unevenly, what may be the result?
10. If a blow torch were applied to the cone, would it loosen the cone or would it expand the spindle as fast as the cone?
11. If the cone should become too hot what harm would result?
12. How could the cone be heated a moderate amount without heating the spindle?

Job No. 6

REPLACING BUSHINGS AND PINS IN KNUCKLE ARMS

References.—Part Two, p. 343.

Operations Necessary to Perform the Job.

1. Block up car.
2. Disconnect tie rod.
3. Remove knuckle arm.
4. Remove bushings.
5. Install new bushings and pins.
6. Ream bushings if necessary.
7. Replace arm and finish job as in straightening knuckle arm.

Description of Operations.

When the bushings and pins in the knuckle arms have become worn sufficiently to allow the front wheels to " wobble," the repairman should disconnect the tie rod and remove the knuckle arms if they are detachable. If they are not detachable, it will be necessary to remove the whole knuckle assembly.

The worn bushings should be forced out and new bushings installed; ream the bushings until a running fit has been obtained.

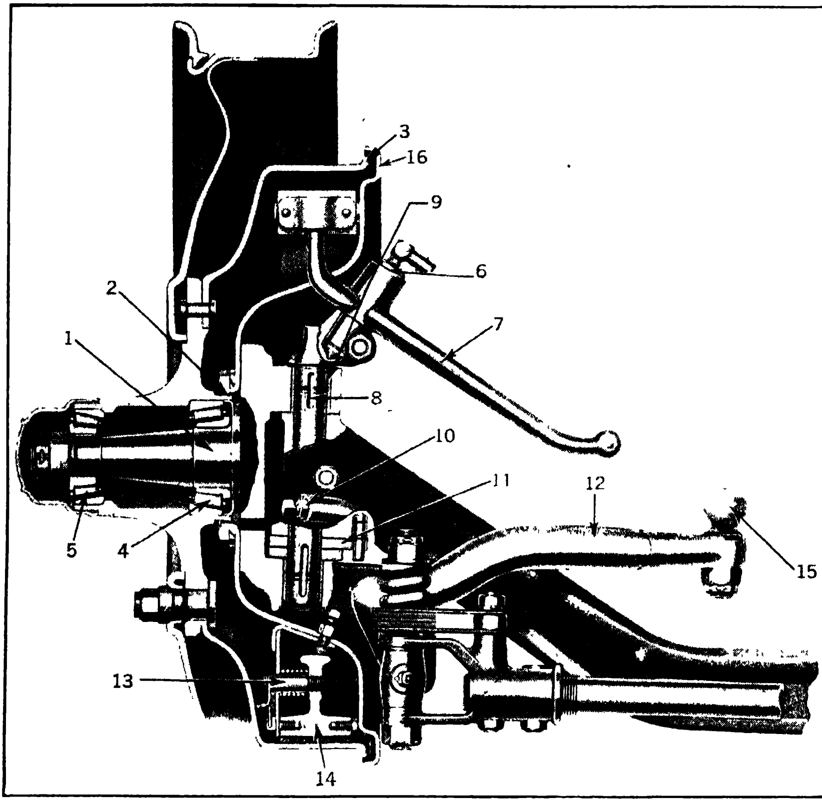


Fig. 6a.—Front Axle and Steering-knuckle. (Nash, 1928.)

1 Steering-knuckle
2 Dust shield r.
3 Clearance between drum and flange.
4 Inner Roller bearing
5 Outer roller bearing.
6 Brake-operating lever pin.
7 Brake-operating lever
8 Steering-knuckle pin
9 Steering-knuckle pin bushing
10 Steering-radius adjusting screw and lock nut.
11 Knuckle thrust plates
12 Steering-knuckle arm
13 Brake pressure plate stud
14 Brake shoe
15. Steering arm ball

Questions.

1. What are the indications that the knuckle bushings are worn?
2. How are the bushings removed?
3. What are the different kinds of front axles? Part II, p. 352.
4. Which type is used most on modern cars?

5. What is the principal difference between the Elliott and the reversed Elliott types?
6. Is it necessary to remove the arms from the knuckle in order to remove the bushing?
7. When should a new bushing be reamed, before or after installing?
8. How tight a fit should be made?
9. What kind of hammers will a good mechanic use when striking machined parts of a car?
10. What final check should always be made for every job?

Job No. 7

REMOVING FRONT-WHEEL "SHIMMY."

References.—Part Two, p. 343.

Operations Necessary to Perform the Job.

1. Jack up front of car.
2. Inspect caster of axle, knuckles, steering device, spring tie bolts, spring clips, spring bushings and hangers.
3. Check wheel alignment. (Job 8.)
4. Inspect axle; straighten if necessary. (Job 3.)
5. Insert wedges if necessary.
6. Replace spring if necessary. (Job 2.)
7. Replace bushings in spindle bodies and arms if necessary. (Job 5.)
8. Replace wheel bearings if necessary.
9. Take up play in steering mechanism. (Job 9.)
10. Reassemble all parts.
11. Align wheels. (Job 8.)

Description of Operations.

Removing "shimmying" from the front wheels requires good judgment on the part of the mechanic. If may be caused by a number of things. There are, however, some very important items to be checked first. One is the caster of the front axle. The axle should have a slight pitch, as described in Job. No. 8. This pitch must be corrected if it is not properly adjusted. Check up to discover whether the front axle is straight. If it is bent, a "shimmy" will result. The caster can be restored by replacing the sagged front springs with new springs or by inserting wedges between the axle and the springs at the spring saddle. In case the axle is bent, it is necessary to dismantle the front system and straighten it. Numerous other things, such as play in the steering

mechanism or knuckle bushings, and worn pins, may also cause looseness in the front system and the resulting "shimmying" of the front wheels. The frame itself may be out of line. In this case it is necessary to straighten the whole frame. After all these things are corrected it will usually be found that the "shimmying" has disappeared. There are "shimmy springs" manufactured that can be used as an emergency repair on the front system; in most cases these will eliminate the trouble.

Questions.

1. What causes front wheels to "shimmy"?
2. What can be done to remedy this condition?
3. Where are the wedges placed?
4. Which way should the front axle be tilted?
5. Is it necessary to align the front wheels after assembling?
6. Will taking the play out of the front system remedy shimmying?

Job No. 8

LINING UP FRONT WHEELS

References.—Part Two, pp. 382-3-4.

Operations Necessary to Perform the Job.

1. Block up front axle.
2. Inspect bearings in steering mechanism and wheels.
3. Test front axle for alignment and make adjustments.

Trade Terms to be Reviewed before Performing the Job.

Operations.—Lining up wheels, "toeing in," "camber," "caster."

Description of Operations.

Improper alignment of the front wheels causes difficult steering and unnecessary wear on the front tires. The alignment should be inspected periodically. Very often the wheels are thrown out of line by striking curbs or obstructions. When lining up the front wheels, block up the front axle and, after making certain that no extra play exists in the wheel bearings or in the bearings of the steering mechanism, check the wheels to determine whether the "camber" is correct.

The "camber" is set at the factory by inclining the spindle downward a distance of about two to five degrees, which in turn sets each front

wheel in at the bottom the same angle (Fig. 8*a*). The " camber " may be lost if the front axle or spindle becomes bent and may be remedied according to instructions given in Jobs No. 3 and No. 5. If the knuckle bushings or the wheel bearings are worn or improperly adjusted, this, too, will affect the " camber " and the trouble should be repaired.

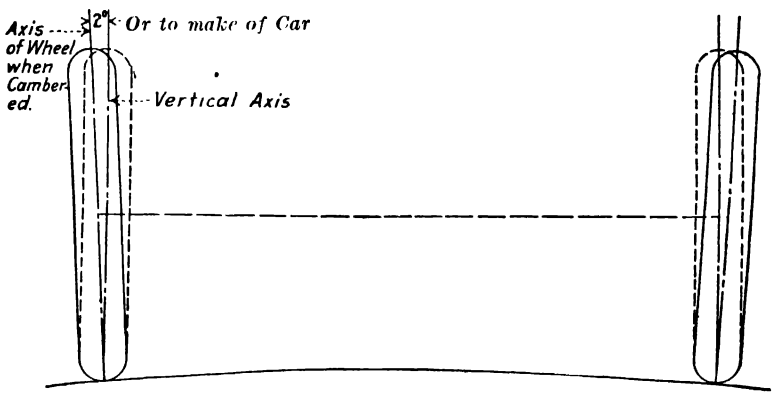


FIG. 8*a*. Showing "Camber Set " of Front Wheels.

The " toe in " (Fig. 8*b*) should be checked carefully, and adjustments made, if necessary.

Check to see if the " caster " is satisfactory. This may be determined by placing a steel square (Fig. 8*c*) on a level floor, with the blade

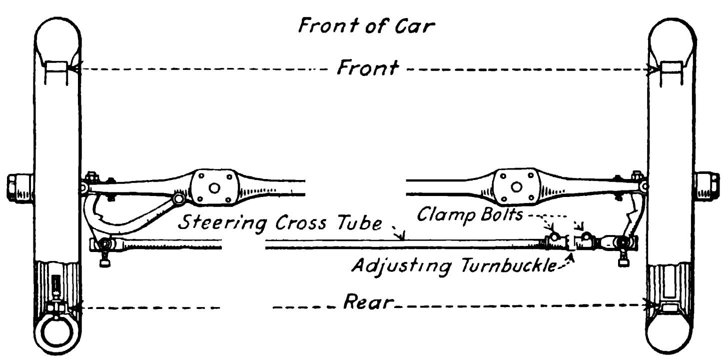


FIG. 8*b*.—Measurements for "Toe In."

or heel touching the lower axle yoke (*c*). The distance from the upper axle yoke (*x*) to the square should average about $\frac{1}{4}$ inch.

The " caster " is set at the factory and may be lost because of a twisted axle or sagging springs. If the latter is the cause the repair-

man should either install new springs or insert wedges (Fig. 8*d*) between the springs and spring seats on the side of the axle. This wedge will tilt the axle forward or backward as may be necessary to restore the correct amount of caster. The repairman should next line the front axle to the rear axle and frame and remove the blocking.

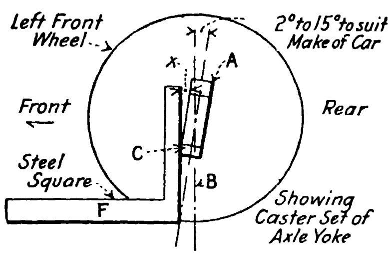


FIG. 8*c*.—Showing "Caster Set" in Front Wheels.

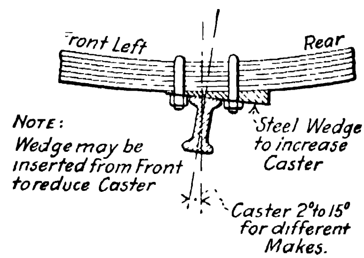


FIG. 8*d*.—Adjusting "Caster Set" of Front Wheels.

Questions.

1. Should the front wheels of a car or truck be parallel? Should they be closer together at the front or should they be spread at the front? Why?
2. What is meant by "gather" or by "toe in"?
3. How much "toe in" is desirable?
4. What provision is made by the designer to permit adjustment of the amount of "toe in"?
5. Should the wheels be closer together at the ground or at the top? Why?
6. What is meant by camber?
7. Will this remain the same when the steering-knuckle bushings and pins become worn?
8. What is meant by wheel tread?
9. How much is the standard wheel tread?
10. If no special gauges are available, how can the alignment of the front wheels be tested?
11. Will the test be accurate if the front wheels are sprung or run out of true?
12. How should the front wheels be tested to determine whether they run out?
13. If the distance between these lines is measured at the farthest point forward and again at the farthest point toward the back (at the height of the hubs) should the dimensions be the same?
14. If the steering-knuckle bushings and the tie-rod ends are worn and loose, what precaution should be taken to insure that the setting made will be such that the wheels will have the proper "gather" or "toe in" when running on the road?

15. With the tie rod removed, would the front wheels tend to spread or to "gather" as the machine is rolled forward?
16. When a car or truck turns a corner, which front wheel has to make the shorter turn?
17. Are the arms on the steering-knuckles parallel?
18. To what place should they point, approximately, in order that the front wheels will track properly on a turn?
19. What effect does this have on the steering, or on the tendency of the car to follow the road?
20. Will the alignment be satisfactory if there is a large amount of play in the knuckle pins and bushings and in the tie rod and steering connections? Why?

Job No. 9

REMOVING "LOST MOTION" FROM STEERING MECHANISM

References.- Part Two, p. 352.

Operations Necessary to Perform the Job.

1. Block up front of car.
2. Inspect tie rod for lost motion.
3. Replace with new bushings and pins, if necessary.
4. Inspect drag-link bearings and make necessary adjustments.
5. Examine steering-gear arm; tighten if loose.
6. Examine steering-mechanism and make necessary adjustments.
7. Lubricate all working parts and see that all adjustments are properly locked.

Names of Materials, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Parts.- Steering-gear case, cover, bracket, steering arm, shaft, steering-wheel spider, steering-wheel tube, spark and throttle sector, spark and throttle sector tube, spark hand-lever, throttle hand-lever, steering worm, worm sector, worm shaft, cam and trunnion shaft, headlight control, horn button.

Description of Operation.

After prolonged service, an excessive amount of play or lost motion, due to wear, may develop in the steering gear. Before a readjustment of the gear is undertaken, tests should be made to make sure that the lost motion is not at some other point in the steering mechanism. Lost

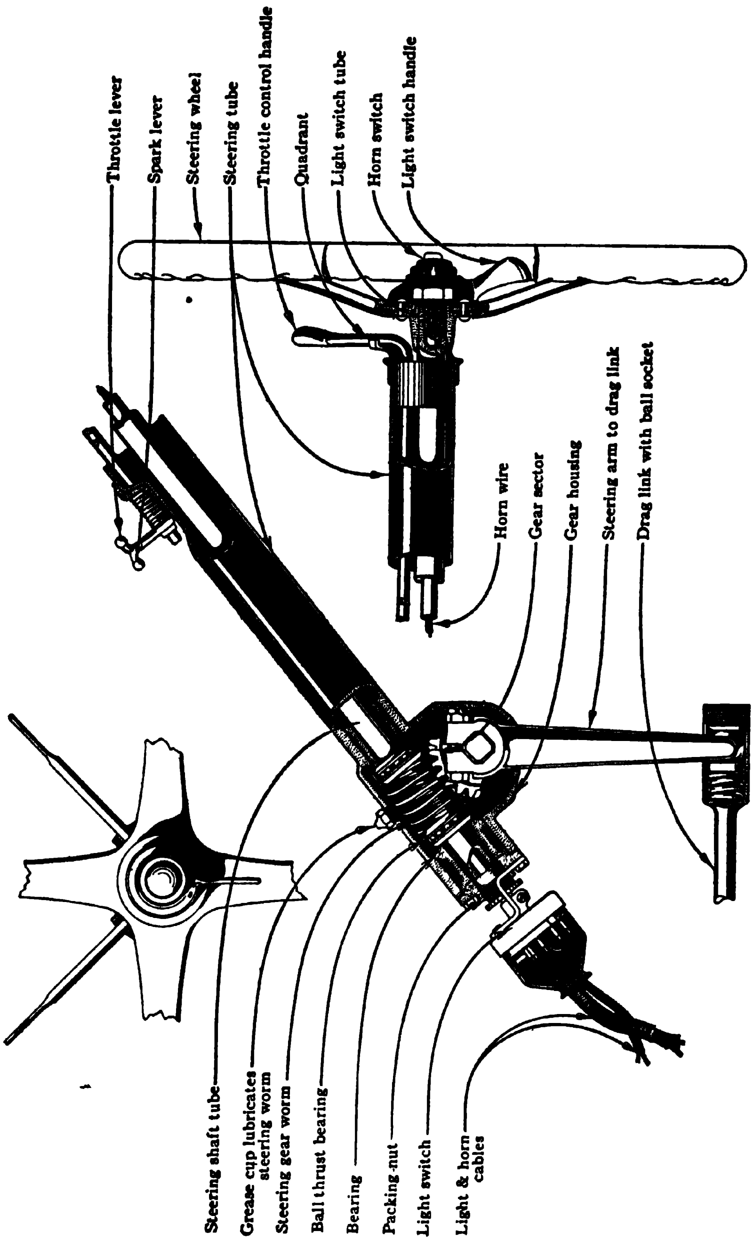


FIG. 9a.—Steering-gear, Worm and Sector Type. Model "A" Ford.

motion may develop at the reach-rod ball sockets and steering-knuckle pins. End play in the gear can be reduced by loosening the clamp on the gear housing and turning the nut (Fig. 9*b*) to the right until the amount of play is satisfactory and the steering wheel turns freely. The clamp should then be retightened.

The drag link connects the steering arm of the gear to the knuckle arm on the front axle and is of vital importance. This link should be inspected at regular intervals for lubrication and proper adjustment. In adjusting ball sockets it is important that the cotter keys be replaced,

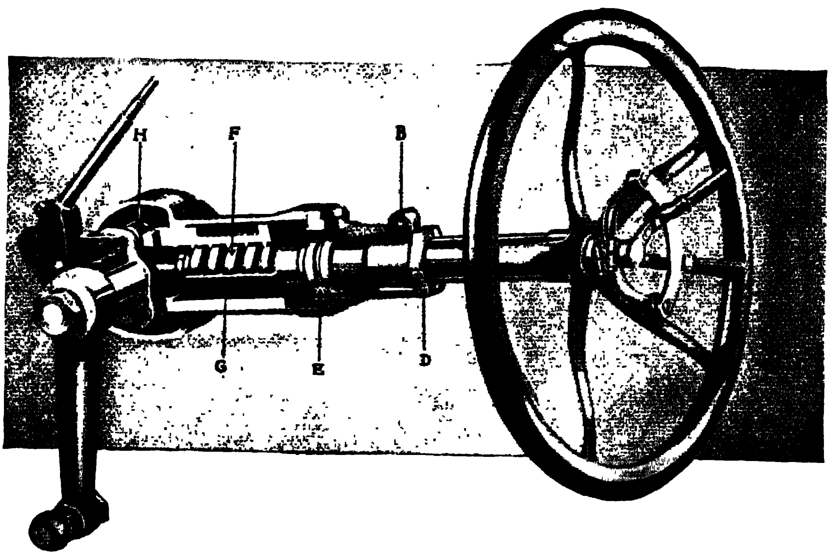


Fig. 9*b*.—Steering-gear, Screw and Nut Type.

B—Adjustable nut clamp.
D—Adjustable split nut.
E—Thrust bearing
F—Screw
G—Half nuts.
H—Rollers on rocker shaft.

as omission of them may result in the drag link working loose, and a serious accident may happen.

There are four important features which a steering gear must possess in order to give satisfaction to the engineer, the owner, and the service department, namely, power, uniformity of action, durability, and facility of adjustment. Figure 9*b* shows a semi-reversible gear of the screw and nut type.

The principal parts of this gear are the steering screw, a right and left-handed half-nut, a rocker shaft, a ball thrust bearing, an adjustable

screw, and a case or housing. The steering screw has right- and left-handed threads which cross each other at each half turn and of the proper shape to mate with the thread in the half nuts. Turning the hand wheel rotates the tube in the column to which the screw is keyed, and as the screw rotates it causes the half nuts to slide in opposite directions. The lower ends of these nuts rest on rollers and operate a rocker-shaft, to which is fastened the steering arm and reach rod, connecting it to the knuckle arm on the front axle.

The steering gear shown in Fig. 9*a* is of the *worm and sector* type. It functions in the same way as the *worm and gear* type except that in the latter the complete gear can be used to allow for wear between the worm and gear.

In adjusting the worm and gear type it is important first to locate where looseness or play exists. Determine this location by having someone move the wheel back and forth, while you observe to see if the column itself moves up and down, indicating end play in the worm. This can be overcome by tightening the adjusting nut at the top of the housing. If close observation shows end play on the gear shaft, this can be overcome by tightening the gear-adjusting screw on the cover.

If there appears to be play between the gear and the worm, the gear can be moved to a closer mesh with the worm by turning the eccentric bushing adjustment. When the bushing has been moved around to the point where all adjustment has been taken up, a new part of the gear can be brought into mesh with the worm by revolving the steering tube until the gear has made one-quarter of a revolution. In making this adjustment, the eccentric bushing should be moved back to give all the adjustment possible with the gear properly meshed with the worm.

If play is found to exist where the steering arm goes on the shaft, it can easily be taken out by tightening up the clamp screw. Play sometimes develops in the drag-link connections either at the steering gear or at the front axle, and this can be taken out by tightening up the adjusting plugs in the ends of the drag-link connections. Be sure that all adjustments are properly locked.

There is still another popular kind of steering gear which is called the *cam* and *lever* type. This was adopted with the coming of the balloon tire, because of its leverage which enables the driver to turn the front wheels easily against the increased road friction caused by low-pressure tires. This type of steering gear is provided with two adjustments for wear. It is better to remove the drag link before adjusting. The thrust bearings, above and below the cam, at the lower end of the steering tube, are adjusted by turning the thrust-adjusting nut clockwise to tighten the

bearing. This regulates the vertical movement of the steering tube. After this has been adjusted, lock the lock screw. In some cam and

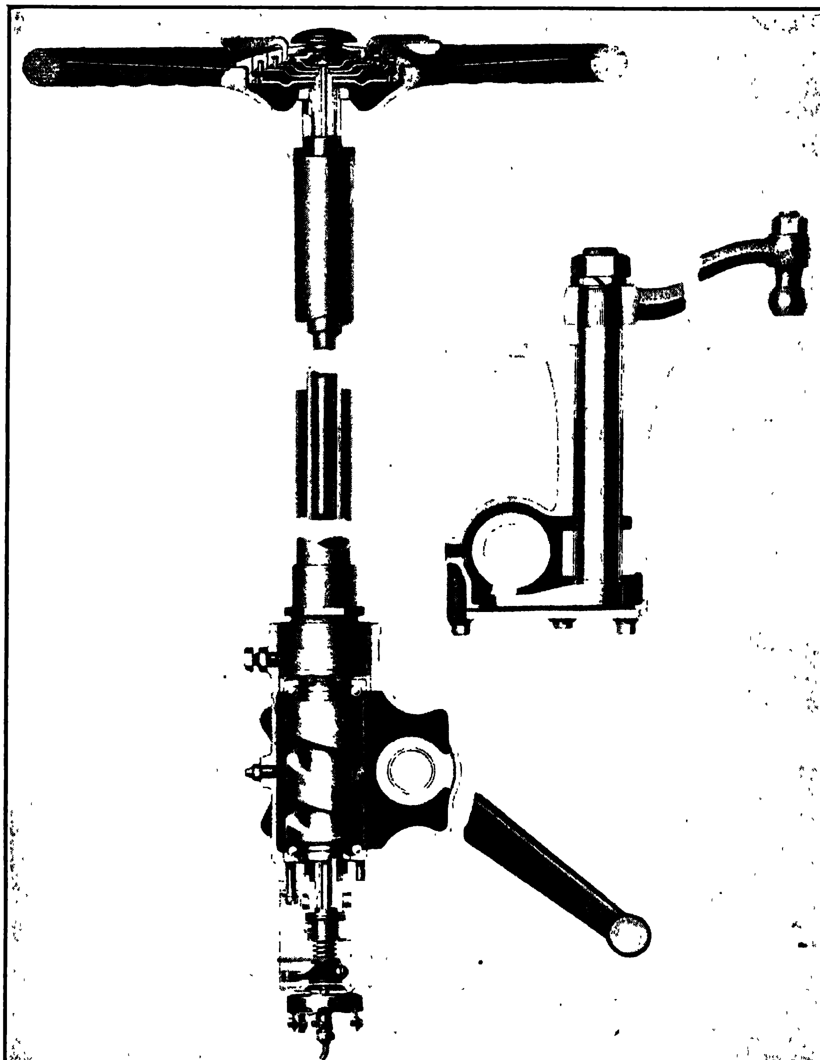


FIG. 9c.—Cam and Lever Steering Gear.

lever types, this vertical play is adjusted by removing shims from the top of the cam. There is one more adjustment, for backlash. This can be adjusted by removing shims from between the housing and the

cover housing until the lost motion disappears. Replace drag link and lock all adjustments.

Questions.

1. Is it easy to turn the steering wheel when the car is standing on the floor?
2. Is it easy to determine the amount of play in the steering gear when the car is standing on the floor?
3. If the adjustments are taken up, can binding of the parts be detected while the car is standing still?
4. What should be done with the front end when the steering mechanism is to be checked up and adjusted?
5. Will looseness in knuckle pins have any effect on ease of steering?
6. How should the amount of looseness be determined?
7. What is the name of the rod which connects the two steering-knuckles?
8. What is the name of the rod which connects the bottom of the steering gear with one of the steering-knuckles?
9. What kind of joints does it generally have?
10. How should these be tested for looseness?
11. How should this looseness be taken up?
12. If the car or truck is to be driven in a sandy country or in wet weather, what provision should be made to exclude sand and water?
13. How should the joints be lubricated?
14. What effect will lack of lubrication have on the balls and cups?
15. How can it be determined whether the lost motion noticed at the wheel is mostly in the joints in the rods or mostly in the steering gear?
16. If the adjustment is too tight, what difficulty may be experienced in steering?
17. What adjustment is provided on a worm-type steering gear to take up the play?
18. Where is the adjusting device located?
19. Where is the adjustment located in a screw and split-nut steering gear?
20. Where is the thrust bearing located?
21. What lubricant should be used in the lower part of the steering gear?
22. If a bevel pinion and sector-type steering gear are used how may the pinion be adjusted to the sector?

Job No. 10

INSTALLING NEW GEARS IN THE DIFFERENTIAL

References.—Part Two, p. 353.

Operations Necessary to Perform the Job.

I. For *full-floating axle:*

1. Block up axle housing and remove hub cap.
2. Pull axle out of housing.

3. Remove differential inspection plate and bearing caps.
4. Lift differential out.
5. Remove bolts holding differential housing together.
6. Clean all parts, including rear-axle housing.
7. Remove differential gears.
8. Test new gears for correct mesh and clearance.
9. Reassemble differential and replace in axle.
10. Replace axle.
11. Connect axle to wheels.
12. Make proper tests and necessary adjustments.
13. Replace inspection plates with gaskets and remove blocking.
14. Put necessary lubricant in housing.
15. Test axle for sound by running on blocks.

II. For *a three-quarter floating axle* not using a split collar, proceed as above. If split collars are used, collars must be removed before axle can be pulled out; then proceed as in case of full floating axle.

III. For *a semi-floating* axle, proceed as with three-quarter floating axle, using split collars.

IV. For *a plain live axle* or type using a split housing:

1. Block up frame.
2. Disconnect torque tube at universal joint.
3. Disconnect springs, and brake rods.
4. Roll rear assembly out from under car.
5. Remove both wheels.
6. Remove bolts holding axle housings together (grease containers must be provided to catch grease).
7. Slip axle housing off from each side.
8. Remove bolts holding differential housing together.
9. Take differential apart.
10. Clean all parts, including axle housing.
11. Inspect gears for worn or broken parts and replace as necessary.
12. Reassemble differential and make tests for end play in axles.
13. If necessary, put in a thicker disk.
14. Make tests for correct action of differential gears.
15. Replace left side of axle housing and make sure that thrust washers are in right place, with ring gear on left side of axle.
16. Attach torque tube enclosing drive shaft to left side of housing.
17. Test for square application of propellor shaft.
18. Test for correct backlash in ring gear and pinion.
19. Build up or reduce thrust washers as needed.
20. Remove torque tube and put right side of housing in place.
21. Make test for thickness of thrust washers on right side.
22. Build up or reduce thrust washers as needed.
23. Bolt housing together accurately.

24. Attach torque tube.
25. Replace wheels.
26. Replace axle under car.

Names of Material, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Material.—Gasket material, kerosene.

Tools.—Wheel puller, spanner wrench, tool kit.

Parts.—Rear axle. General types.

Dead Axle.—An axle carrying road wheels with no provision in the axle itself for driving them.

Live Axle.—General name for type of axle with concentric driving shaft.

Plain Live Axle.—Has shafts supported directly in bearings at center and at ends, carrying differential and road wheels. (See Fig. 10*a*.)

Semi-floating Axle (Fig. 10*b*).—Has differential carried on separate bearings, the inner ends of the shafts being carried by the differential side gears, and the outer ends supported in bearings.

The semi-floating axle shaft carries torsion, bending moment and shear. It also carries tension and compression if the wheel bearings do not take thrust, and compression if they take thrust in only one direction.

Three-quarter Floating Axle (Fig. 10*c*).—Inner ends of shafts carried as in semi-floating axle. Outer ends supported by wheels, which depend on shafts for alignment. Only one bearing is used in each wheel hub.

The three-quarter floating axle shaft carries torsion and the bending moment imposed by the wheel on corners and uneven road surfaces. It also carries tension and compression if the wheel bearings are not arranged to take thrust.

Full-floating Axle (see Fig. 10*d*).—Same as three-quarter floating axle except that each wheel has two bearings and does not depend on shaft for alignment. The wheel may be driven by a flange or a jaw clutch.

The full-floating axle shaft is relieved from all strains except torsion, and, in one possible construction, tension and compression.

Types of Axle Drives.—The different types of live axles can be driven by bevel gear, spiral bevel gear, worm, or double-reduction gear.

In other constructions, the rear wheels are driven by double chains, internal gears, or jointed cross-shafts.

Housing.—Rear-axle housing, right and left halves, bevel (or worm) gear housing, right rear-axle tube, left rear-axle tube, rear-axle-housing

cover, differential carrier, rear-axle spring-seat, axle brake-shaft bracket, brake-support, brake-shield.

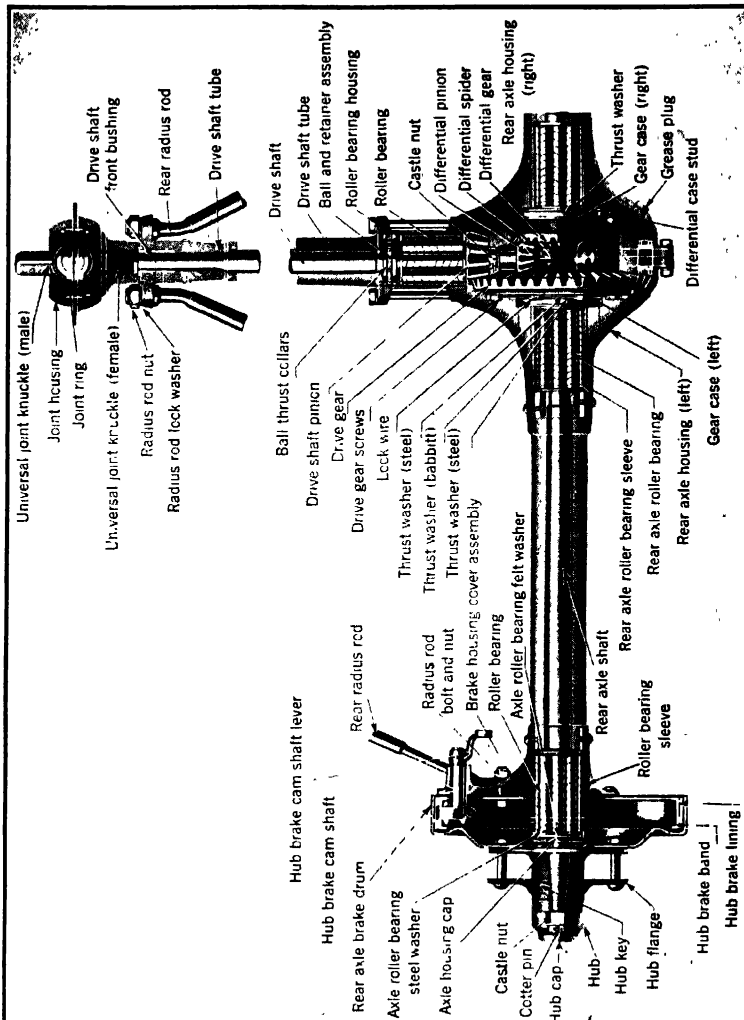


FIG. 10*a*.—Plain Live Axle. (Model T Ford.)

Torque-arm and Radius-rod.

Differential.—Axle drive, bevel (or worm) gear, differential, differential case, differential side gear, differential pinions, spider, bearings, thrust-bearing, bearing adjuster, bearing-adjuster lock.

Axle Shafts.—Axle shaft (right and left), axle-shaft wheel-flange (or clutch).

Operations.—Blocking or jacking up car.

Stock Regulations or Working Properties.—Selection of gears having correct pitch and number of teeth.

Care of Equipment.—Clean and oil parts. Make no adjustments until locking device is loosened, lock all parts before final assembly. Exercise care in the removal of bearings, in making correct bearing adjustments, and in tightening nuts on assembled parts, such as rear-axle housing, to bring same pressure at all points.

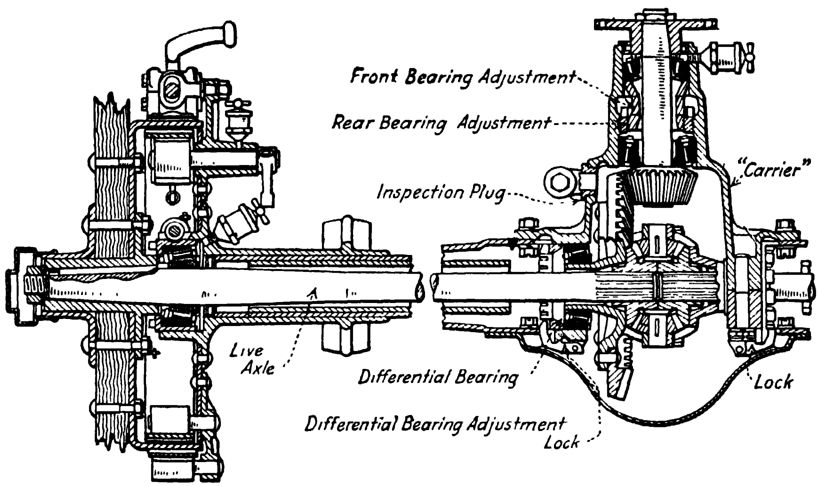


FIG. 10*b*.—Semi-floating Rear Axle.

Description of Operations.

If the rear end of a car using a full-floating axle (Fig. 10*d*) requires the installation of new differential gears, block up the axle housing until both wheels clear the floor, disconnect the axles from the wheels, pull both axles from the axle housing, and then remove the differential inspection plate. This plate is held in position by a series of cap screws. The bolts holding the differential bearing caps should then be removed and the differential lifted out. The bolts which hold the differential housing halves together may now be removed.

All parts, including the differential housing, should be cleaned with kerosene. All worn or broken differential gears should be discarded, and new gears installed and the differential housing halves bolted together. The repairman will usually find that new differential gears

mesh properly. It is best, however, to make sure that the gears have sufficient backlash to insure freedom of action.

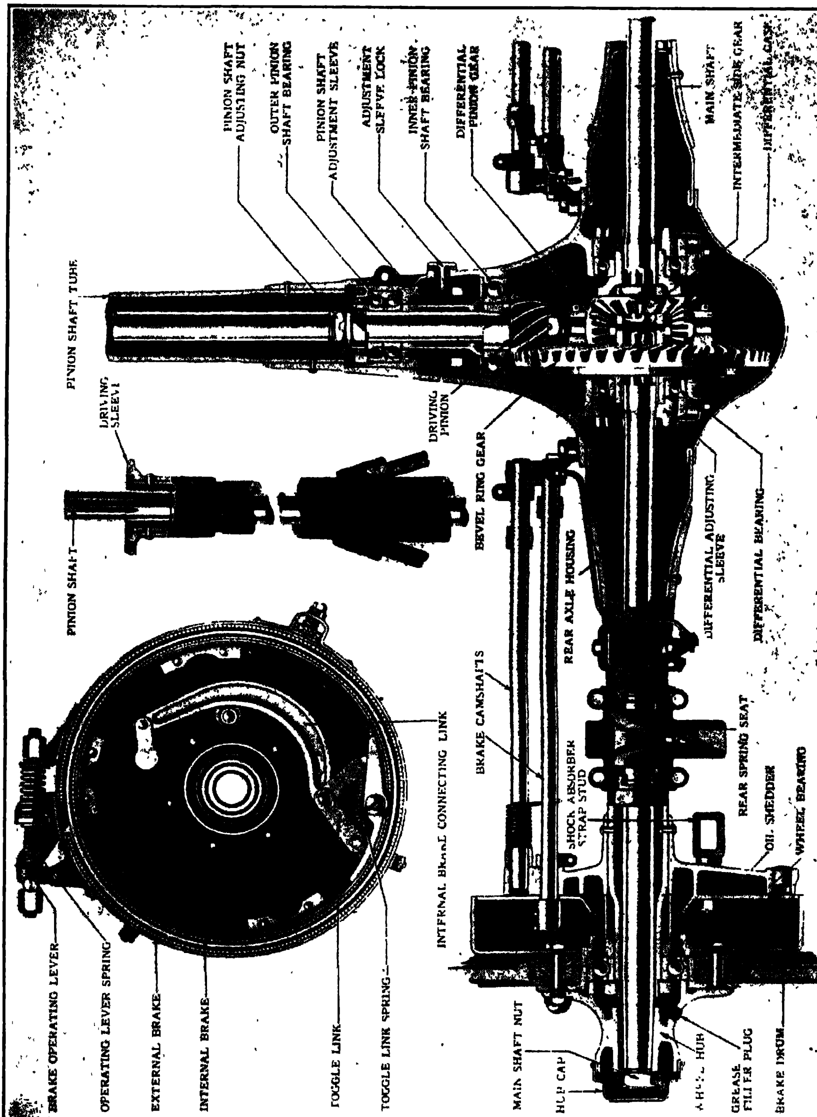


FIG. 10c.—Three-quarter Floating Rear Axle.

While the differential is out of the housing the bearings and other parts should be examined for wear. In reassembling make certain that

the wire used to lock the differential housing bolts is properly laced in position, and then replace the differential in its carrier.

After the differential bearing caps and bolts have been replaced, care must be taken not to screw the bolts down too tight, until the proper backlash has been obtained between the ring gear and the drive pinion. The axles should now be replaced and the connections made at the wheels.

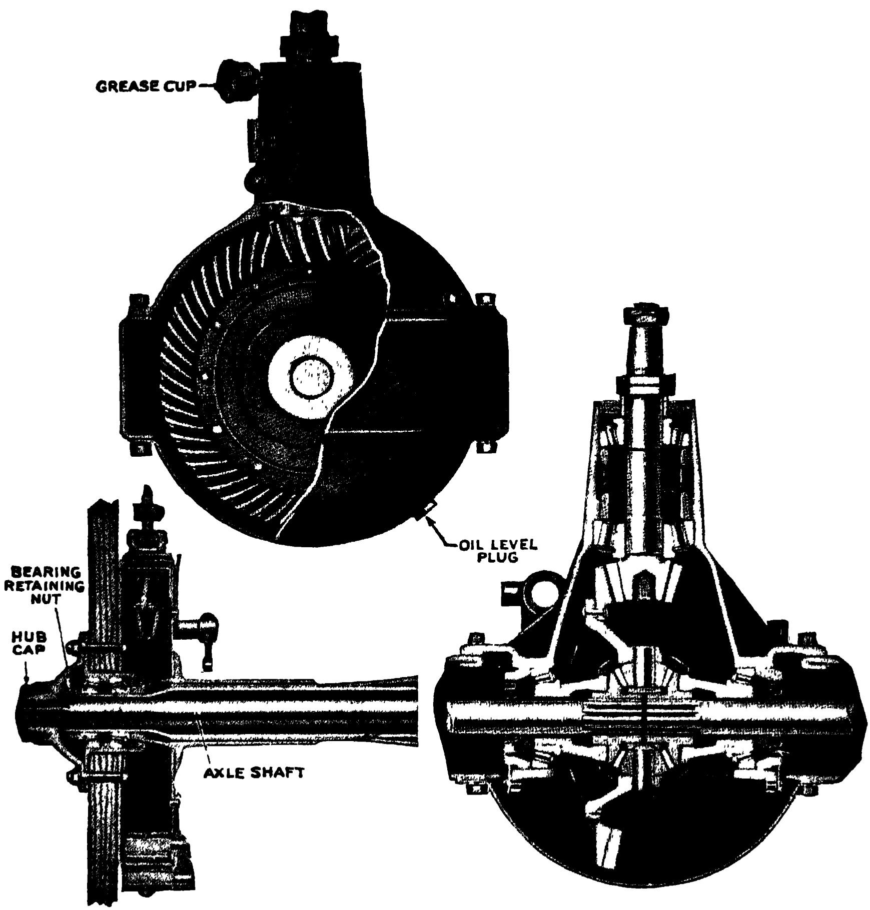


FIG. 10*d*.—Full-floating Rear Axle.

There are so many different makes and models of cars on the market to-day that to give specific instructions for adjusting all differentials would make this discussion too lengthy for practical use. While the differential adjustments can be made very easily by the average mechanic

even though he is not familiar with the make of the car, it is a good plan for him to consult the manufacturer's instruction manual whenever he is in doubt as to the correct adjustment.

Before making the final adjustments the repairman should put a small quantity of lubricant in the housing and start the engine, with the high gear in mesh. The adjustments should be made according to the foregoing instructions until the ring gear and the drive pinion are meshing satisfactorily and with the least noise. When the adjustment is satisfactory stop the engine and inspect the rear axle to see that the bearing caps are screwed down tight and that all adjustments are locked. Replace the inspection plate and fill the axle housing with the correct amount of lubricant.

When the repair work is to be done on a car using a three-quarter axle which does not use split collars, the instructions on the full-floating type can be followed in a similar way. Should split collars be used the collars must be removed before the axles can be pulled from their housing. In this type the adjustments are located differently from the full-floating type. If a little study does not enable the repairman to make the adjustments he should consult the Instruction Manual for that particular car and then complete the job as for a full-floating type.

If the repairman follows the instructions given for cars with a three-quarter type axle using split collars, he will not meet with much difficulty when doing the same job on a car using a semi-floating axle. When it becomes necessary to install new differential gears in a car using a plain live axle, such as is used on the Ford * car, it necessitates the complete removal and taking down of the rear-axle assembly. In this case use a hoist and block up the body of the car, placing the blocks in such a position that they will not interfere when the axle assembly is rolled from under the car. Disconnect the torque tube at the universal joint and remove the bolts at the spring seats or shackles. Now disconnect the brake rods, remove the axle assembly from under the car, and remove the wheels.

The assembly should be placed on some suitable stand and the radius rods disconnected. Remove the nuts where the torque tube is fastened to the axle housing, remove the torque tube, propeller shaft, and drive pinion, and drain out all the old lubricant, catching the lubricant in a suitable container. Then remove the bolts holding the two halves of the axle housing together and slip the housing off of the axle, making sure that the inner bearings do not stick. If the axle does not come out easily, do not attempt to drive it out as this only makes matters worse;

* This reference is to the Model "T" Ford. The new Model "A" Ford uses a three-quarter floating axle.

instead, reach into the housing with a screw driver and force the inner bearing out, at the same time removing the housing. The lacing wire and the bolts holding the differential housing halves together should now be removed, and all parts washed in kerosene and inspected.

The axle gears of the differential may now be removed from the axles and the new gears installed, care being taken to see that the gears are forced back against the split ring as far as they will go, that the axle gears do not bind in the housing, and that the axle ends do not bind in the spider.

The repairman is now ready to reassemble the differential. After making sure that the fiber washer is between the axle ends, bolt the differential housing together. If the fiber washer is too thick it will force the axle gears too tight against the inside of the differential housing and will cause these gears to bind. In this case dress down the fiber washer or replace it with a new one. If, on the other hand, this washer is too thin, it will cause end play in the axles which results in broken spider pinions. After these adjustments are all made, the lacing wire should be replaced and the differential assembly inserted in the left half of the axle housing with the ring gear on the left side.

The next operation is to see that the thrust washers are in their proper position. Dowel pins are provided for this purpose. Should these pins become worn to the extent that they will no longer retain the thrust washers, the old pins should be drilled out and new ones installed. The torque tube with the propeller shaft and pinion should be bolted to the left half of the axle housing after the repairman has made sure that this shaft is setting square with the housing. He is now ready to test for backlash between the driving gears by running a piece of ordinary writing paper between the gears. If this operation cuts the paper, the mesh is too tight and the thickness of the thrust washers must be reduced. On the other hand, if the paper is not sharply creased, the ring gear is too far from the pinion and the thrust washer must be exchanged for a thicker one. Should the paper show a good plain crease without cutting, it can be taken for granted that the washers are of the proper size.

The torque tube may now be removed and the right side of the housing replaced. The axle fit in the roller bearing should be tested, and the thrust washers on the right side should be built up or reduced according to the end play after the axle housing is bolted together.

The lubricant should now be put in the housing, the torque tube and radius rods connected, the wheels replaced, and the whole rear assembly rolled under the car and connected up. The brake rods should then be adjusted and the blocking removed.

Questions.

1. What is the purpose of the differential?
2. What are the different types of differentials?
3. What are the types of rear axles?
4. What are the essential differences in each type?
5. In the ordinary type of differential is the turning effect applied to one or both wheels when a car turns a corner?
6. What is meant by a live axle?
7. What is meant by a dead axle?
8. How will the repairman know when too much backlash exists in the rear axle?
9. How do you obtain access to the differential of a plain live axle?
10. How should you remove an axle gear from the shaft?
11. What tests should be made before reassembling a rear axle?
12. What is the purpose of the thrust washer?
13. What will happen if this thrust washer is too thick? If too thin?
14. What final tests should be made after all parts are assembled?

Job No. 11

INSTALLING A NEW RING GEAR AND PINION

References.—Part Two, p. 353.

Operations Necessary to Perform the Job.

1. Remove rear assembly from car as directed in Job No. 10.
2. Remove differential, ring gear, and pinion from rear-axle housing as shown in Job No. 10.
3. Clean all parts.
4. Remove old rivets or bolts on ring gear.
5. Remove ring gear.
6. Select and fit new ring gear to new pinion and to differential housing.
7. Use temporary bolts for clamping gear while riveting. (If permanent bolts are used, they must be locked with wire lacing.)
8. Select and fit drive pinion to its shaft.
9. Tighten pinion nut and lock.
10. Reassemble all parts.
11. Make necessary adjustments.
12. Lubricate axle.

Names of Material, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Parts.—Ring gear, axle-drive bevel pinion (or worm).

Material.—Rivets, bolts, wire.

Operations.—Fitting ring gear and pinion.

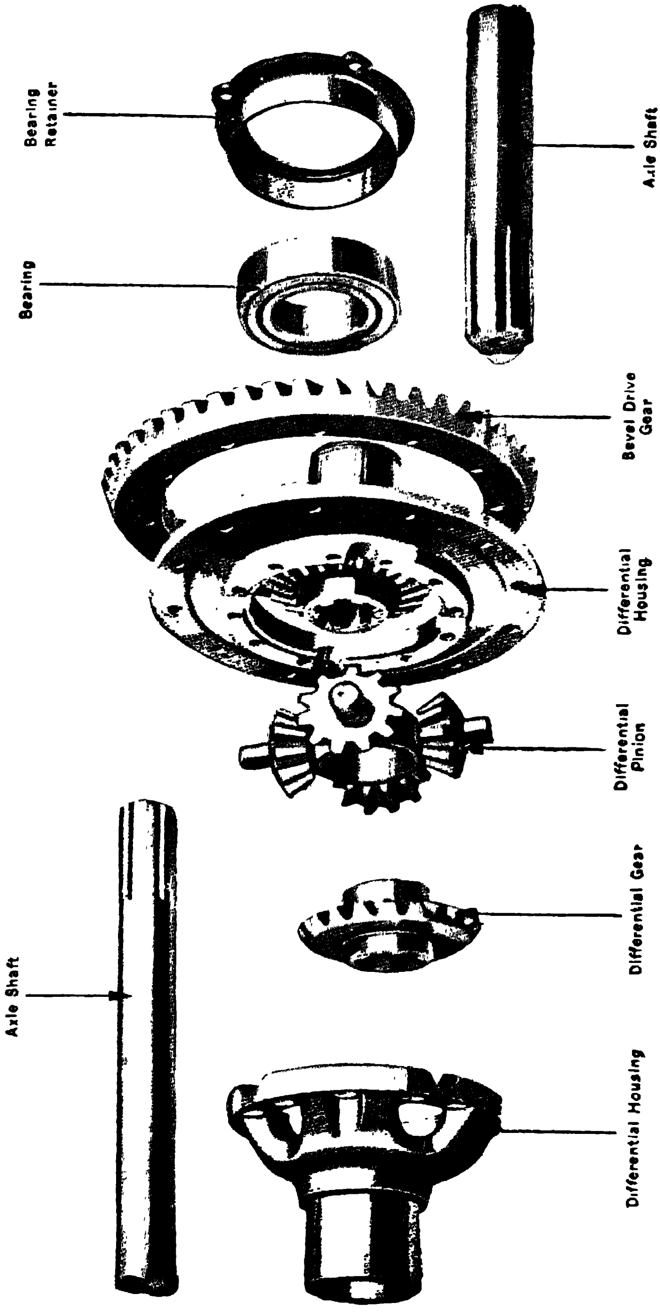


FIG. 11a.—Differential Parts. (Marmon.)

Description of Operations.

To install a new ring gear and drive pinion, remove the differential assembly in the same manner as described in Job No. 10. Then remove the drive pinion from the shaft to which it is attached, clean the differential and remove the bolts or rivets that hold the ring gear secure to the differential housing. The new gears are now selected (Fig. 11*a*), care being taken to see that the teeth of the ring gear and pinion are of the proper pitch and correct gear ratio. After checking these conditions attach the ring gear to the differential housing. If rivets are used, temporary bolts should be used to clamp the gear while riveting. If bolts are inserted, a wire lace must be used to lock the bolts. Whether bolts or rivets are used care must be taken to see that a uniform pressure is brought to bear at all points between the ring gear and the housing.

The pinion is next fitted to the shaft and drawn tight by turning the castellated nut and locking it with a cotter key.

All oil should be replaced with new oil and all parts assembled with the necessary adjustments according to instructions given in Job No. 10.

Questions.

1. Explain how the ring-gear and pinion adjustment may be made for each of the four different types of axles.
2. In what way will the installation of a new ring gear and pinion differ for each of the types of rear axles?
3. What test should be made before the installation of new ring gears and pinions?
4. How is the ring gear attached?
5. How are the ring and pinion gears adjusted for correct mesh?
6. What will be the result if they are fitted too tight or too loose?

Job No. 12

INSTALLING NEW BEARINGS IN REAR AXLE HOUSING

References.—Part Two, pp. 363 to 366.

Operations Necessary to Perform the Job.

1. Remove and inspect all bearings for broken or worn parts.
2. Replace parts as necessary.
3. Make adjustments.
4. Lubricate and reassemble as in previous job.

Description of Operations.

To install new bearings, the different types of axles are taken down as previously described, the bearings cleaned and inspected for defects, new

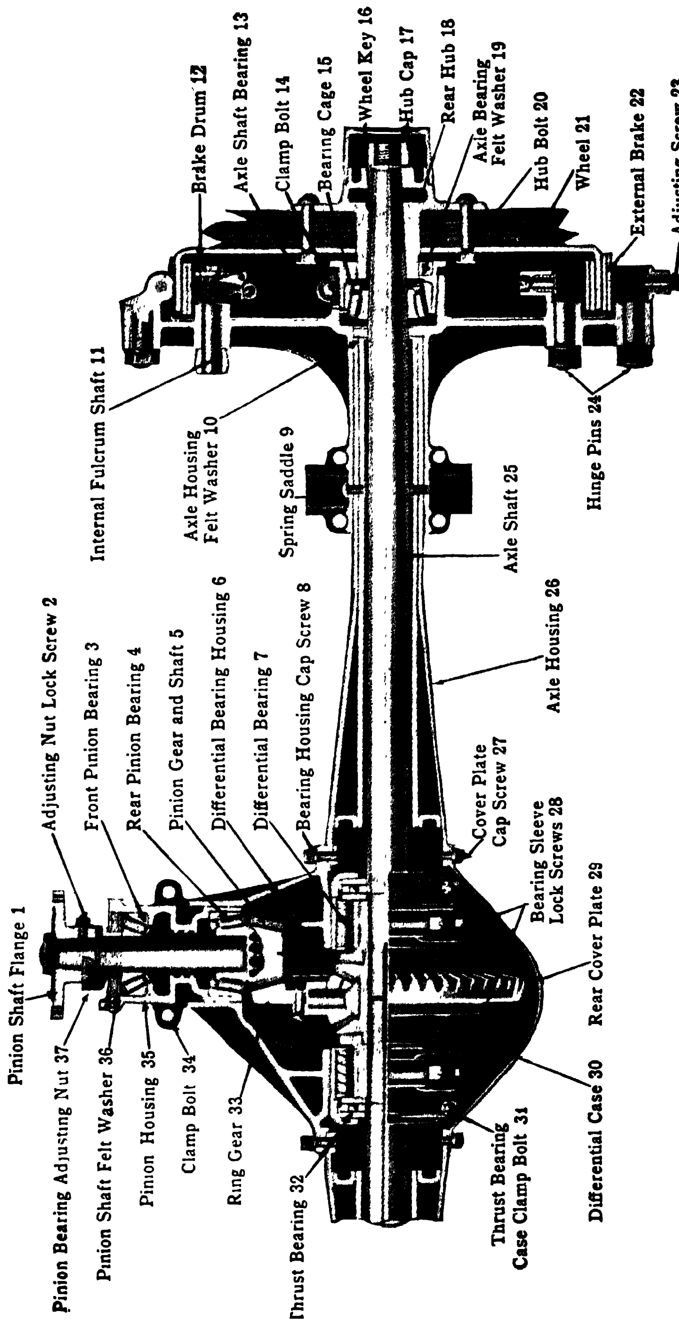


FIG. 12*a*.—Typical Rear Axle Showing Location of Bearing Adjustments.

bearings ordered, if needed, and replaced in accordance with the instructions for adjustments given in previous jobs. After the installation,

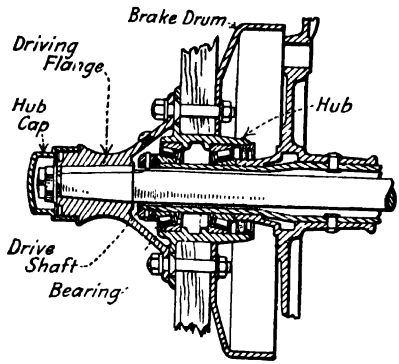


FIG. 12b.—Tapered Roller Bearings.

all adjustments must be made in accordance with the instructions given in the manufacturer's handbook for the particular car.

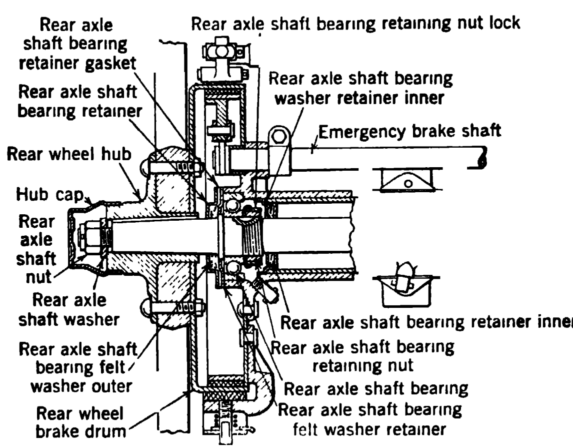


FIG. 12c.—Ball Bearing.

Questions.

1. What tests should be made before installing new bearings?
2. Can broken balls or rollers be replaced with new parts?
3. What types of axle bearings are adjustable?
4. Explain how the different types of axle bearings are adjusted and locked.
5. Which are the better for heavy loads, ball or roller bearings?
6. How is the grease and oil retained in the rear axle?
7. What are the requirements of a good bearing material?

Job No. 13

STRAIGHTENING REAR AXLES OR DRIVE SHAFT

Operations Necessary to Perform the Job.

1. Remove bent axle or shaft.
2. Determine location and amount of bend.
3. Straighten part in a press or lathe.
4. Replace on car, making all necessary adjustments.
5. Make tests, adjust locking devices and replace all parts.

Care of Equipment.

It is better to straighten shafts and other tempered steels not having short bends without heating whenever possible. Heating tends to remove the temper of the metal. Avoid striking the finished or bearing parts of the shaft with a steel hammer.

Description of Operations.

As a rule a bent shaft should be removed from the axle housing and straightened in an arbor press or sent to a machinist to be trued up in a lathe. Oftentimes an axle shaft is bent at the place where it enters the wheel hub, and by removing the wheel it can be sprung into place and trued up with the aid of an old wheel hub placed on the end of the axle and a bar for a lever. The axle should be turned by cranking the engine slowly. As the axle revolves, it is easy to determine just which way to apply the pressure for straightening. The parts taken down are now assembled together with locking devices and the axle tested.

Questions.

1. What are the indications of a bent axle or bent drive shaft?
2. What tools and equipment are needed for straightening a drive shaft or a bent axle?
3. What method is used for straightening a rear axle or a drive shaft?
4. What inspection should be made after straightening an old shaft or installing a new one?
5. What is the purpose of a torque arm?

Job No. 14

INSTALLING NEW KEY IN DRIVE PINION

Operations Necessary to Perform the Job.

1. Remove drive shaft and pinion.
2. Remove old key.

3. Square up keyway.
4. Fit new key.
5. Replace pinion nut and cotter key.
6. Reassemble all parts.

Description of Operations.

When installing a new key in a drive pinion the repairman should take down all parts that will enable him to have free access to the job. Then remove the cotter key from the castellated nut and remove the nut. This will now permit him to force the pinion from the shaft and to remove the old key. After he has selected a new key having the proper curvature, thickness, and width, it should be placed in the key seat on the end of the shaft. The pinion is then matched to the key and forced into place. The castellated nut is then replaced, keyed, and all parts are reassembled and adjusted as before.

Questions.

1. What parts must be removed to gain access to a key in a drive pinion?
2. How will the repairman know when a new key is needed?
3. How must the key for a drive pinion be fitted?
4. How many kinds of keys are used in auto construction?
5. Which is considered the best for automobiles?
6. Are keys tempered or untempered. Why?
7. How are keyways cut?

Job No. 15

INSTALLING NEW HUB

Operations Necessary to Perform the Job.

1. Block up car.
2. Remove wheel.
3. Remove hub.
4. Fit new hub.
5. Press in bearings, if used; if not used, fit to end of axle.
6. Replace wheel.
7. Lock wheel and remove block.

Descriptions of Operations.

When installing a new hub in a wheel (Fig. 4*a*) block up the car and remove the wheel having the defective hub. Then remove the hub flange bolts, separate the detachable flange from the hub, and drive the hub out of the wheel. The new hub and flange should now be

installed and bolted together with new bolts and nuts, and the end of the bolts " swelled " to lock the nuts.

If the wheel is equipped with ball or roller bearings, force the bearing races from the old hub and fit them into a new hub. If the races are too small or are otherwise defective, they should be replaced with new bearing races. The bearings should be cleaned, inspected, and repacked with grease, the wheel replaced, all adjustments made, and the blocking removed.

Questions.

1. What is the best way to remove an old hub?
2. If old hubs contain bearings to be replaced, how should the bearings be removed and replaced in the new hubs?
3. After replacing hubs on wheels keyed to a tapered shaft, how may the repairman make certain that the key is correctly seated?
4. What tests should be applied to the wheel before the job is complete?
5. Why are wheels dished?
6. Why are front wheels "cambered"?
7. Why are front wheels "castered" and how much?
8. What is the average amount of "toe in"?

Job No. 16

REPLACING BROKEN AXLES

Operations Necessary to Perform the Job.

1. Block up rear axle.
2. As a rule it is best to remove both axles. If difficult to remove from housing, punch broken end out from opposite side.
3. Install new axle.
4. Reassemble all parts as before, and remove blocks.

Description of Operations.

When replacing broken rear axles on cars using a plain live axle or any other type in which the axle gears are keyed to the inner ends of the axle, the repairman should proceed to remove and completely take down the rear-axle assembly as instructed in Job No. 10. On some types of cars where one axle is longer than the other, the repairman should, when ordering new parts, specify which axle is wanted by using the term right or left. After the axle gears are forced off the broken axle they should be placed on the new shaft. Gears should not be pounded with a steel hammer unless a block of wood or a piece of lead or brass is used to protect the part. The axle should now be installed, all parts reassembled

and the necessary adjustments made as in Job No. 10. (See Figs. 10*a*, *b*, and *c*, for types of axles.) In case the car has a semi-floating or three-quarter floating type of axle using split collars, it is necessary to remove the differential inspection plate and loosen the split collars a sufficient amount to permit the removal of the axle. Before this is done, however, the car should be blocked up, and after the split collars are loosened the axles may be pulled out with the wheels. Should the broken end of the axle that remains in the housing be too short to be removed easily, take a small iron rod and push the axle out from the opposite side. The job may then be completed as in Job No. 10. Full-floating and three-quarter types of floating axles, using nuts to hold the wheel on the end of the axle tubing, can be removed by taking the hub cap off or unbolting the flange from the wheel. This disconnects the axle from the wheel. The axles may then be pulled out and the flange removed. The flange can then be fitted to the new axle, the axle replaced, and the parts reconnected. This process does not require the blocking up of the wheels unless some adjustments are necessary.

Questions.

1. How is a full-floating axle removed?
2. What precautions should be taken when ordering a new axle?
3. What adjustments should be made when the axle is installed?
4. With a plain live axle, how much of the rear system must be removed to get it out of the housing?

Job No. 17

ADJUSTING REAR WHEEL BEARINGS

References.—Part Two, pp. 363-6; also Job No. 12.

Operations Necessary to Perform the Job.

1. Block up car.
2. Remove axles.
3. Make necessary adjustments.
4. Test bearings.
5. Replace all parts and remove blocks.

Description of Operations.

Through usage the wheel bearings or axle-shaft bearings are subject to a certain amount of natural wear, which, in turn, allows end play to develop in the axle shaft. This can be determined by jacking up both rear wheels and inspecting the wheels for side play.

When adjusting rear wheel bearings block up the rear end and, if full-floating, remove the axles as explained in Job No. 16. Now remove the lock nut and washer from the axle tubing, turn the adjusting nut up tight, and test for a " wobble." If the wheel " wobbles " it may be due to the outer races being loose in the hub or the inner races being loose on the tubing or to the balls or rollers being worn.

If no " play " occurs when the adjusting nut is drawn up tight, the wheel will bind when turned and the nut should be backed off a little to insure freedom in turning and still have no noticeable side shake. The lock washer is now replaced, the lock nut drawn tight, the axles replaced and connected with the wheels, and the blocking removed.

Questions.

1. What are the fundamental principles of ball bearings?
2. What is the difference between an adjustable and a non-adjustable type of bearing?

Job No. 18

LINING UP REAR AXLE ASSEMBLY WITH FRAME

References.—Part Two, p. 343.

Operations Necessary to Perform the Job.

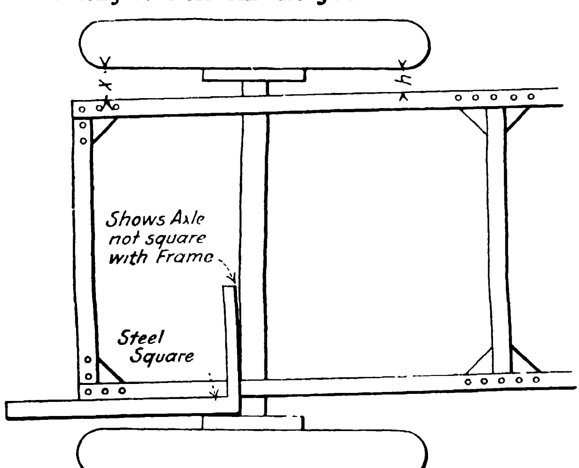


Fig. 18a.—Showing Rear Axle out of Line.

1. Place car on level floor.
2. Make measurements to determine whether the axle is setting in the middle of the frame.

3. Use plumb bob to determine whether the rear axle housing is parallel to rear cross member of the frame.
4. If necessary to shift, loosen spring retaining clips.
5. Lengthen or shorten radius rods as necessary.
6. Replace all parts.

Description of Operations.

The rear axle can be lined with the frame by measuring the distances (x) and (y), Fig. 18a. If these distances are equal the rear assembly is in line with the frame. If the measurements are not equal the spring clips should be loosened and the rear assembly shifted into alignment with the frame. Now take a plumb bob (Fig. 18b) and hold the line next to the outside of the side member, moving the bob until the line touches the side of the tubing, and make a mark at the place where the string touches the side member. Repeat this test on the opposite side and then measure the distance from the rear cross member to the marks. If the rear axle is square with the frame these measurements should be equal. If the distances are not equal loosen the spring retaining clips and lengthen or shorten the radius rods by means of the adjustment nuts until the alignment is correct, and then tighten the spring clips.

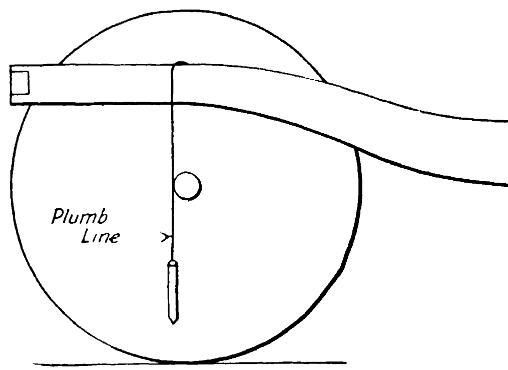


Fig. 18b — Using Plumb Line on Axle and Frame.

Note—Before these tests are made the frame should be tested with a square as in Job No. 1.

Questions.

1. What are the indications of an incorrect alignment of the rear axle with the frame?
2. What measurements are necessary to check the alignment?
3. What may cause the rear axle to get out of line?
4. What damage will result from the rear axle being out of line?
5. Should tests be made on the frame itself before the axle is lined with it?

Job No. 19

ADJUSTING AND RELINING BRAKES

References.—Part Two, p. 366-71.

Operations Necessary to Perform the Job.

1. Block up car.
2. Lengthen or shorten brake-control rods as necessary.
3. Inspect and adjust the brake band around the brake drum.
4. Take up on brake-band adjustments.
5. Make test for correct application of brakes on all wheels.
6. If necessary to reline brakes, remove wheels and brake band or shoe.
7. Remove old lining.
8. Install new lining.
9. Replace brake bands and wheels.
10. Make adjustments and test brake application.

Names of Parts to be Reviewed before Performing the Job.

Outer brake band, band lining, band adjusting nut, band lever, levers and shafts, inner brake shoe, toggle, toggle lever, toggle shaft, cam, brake camshaft, outer brake rod, rod yoke, brake intermediate shaft, equalizer, brake pedal, brake-pedal rod, pedal-rod yoke, pedal pad, brake hand lever, brake lever pawl, segment, rod, button, and spring.

Description of Operations.

There is no part of the car that should receive more careful attention than the brakes, as their failure to operate properly at critical moments may result in serious accident.

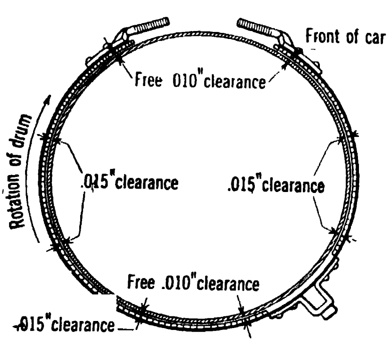


Fig. 19*a*.—Proper Clearance around the Brake Drum.

The service or foot brake should be used for all normal braking purposes. The hand brake should be used only in cases of extreme need to assist the foot brake, or to hold the car when it is left standing.

The slipping of brakes may be due to oil which has found its way out of the wheel bearings and has come into contact with the brake bands. This oil can be removed by washing with kerosene.

Wear on the brake lining will also cause slipping, and if the wear is not so great that new lining is necessary the brake can be readjusted.

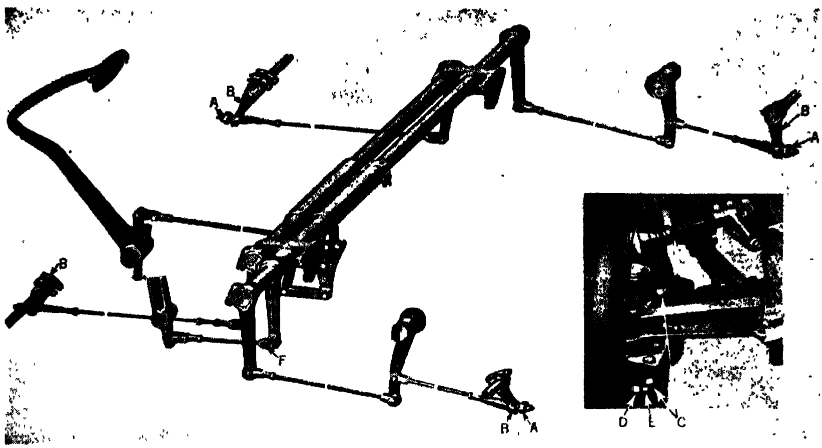


FIG. 19*b*.—Brake-rod Adjustments. (Packard.)

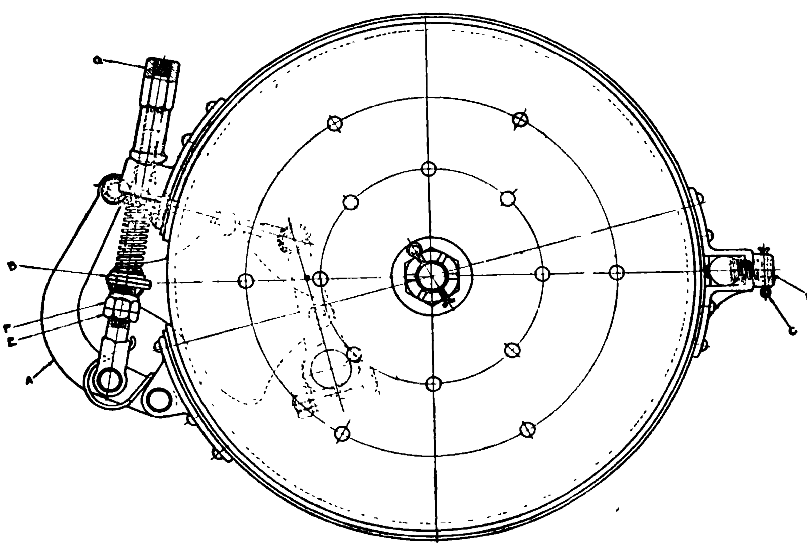


FIG. 19*c*.—Brake Adjustment. (Moon.)

To readjust, jack up wheels clear of the floor. Release the brake levers and examine the brake bands to see if they are concentric with the

drums; that is, the bands should have the same clearance all the way around the brake drum.

First, after jacking up car (four wheels) put all brakes in complete off

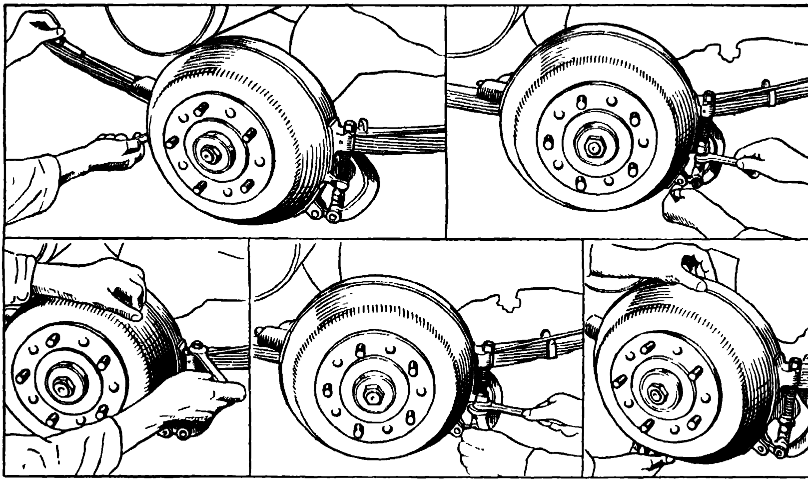


FIG. 19d.—Adjusting Brakes. (Chandler.)

1. Adjusting brake band for clearance at the anchor bracket. Use 0.025-in. feeler gauge for this purpose.
2. Adjusting lower half of brake band for 0.025 in. clearance.
3. Adjusting upper half of brake band for 0.025 in. clearance.
4. Securing lock nuts in position.
5. Testing for brake-band equalization.

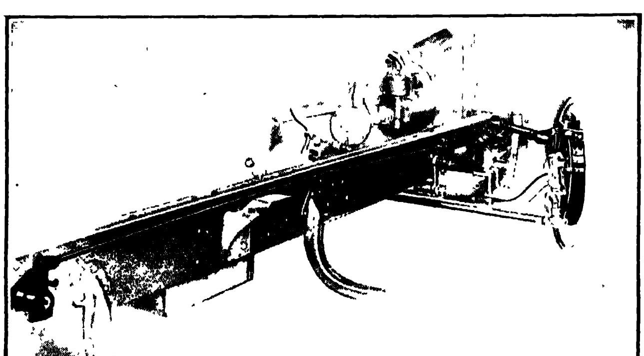


FIG. 19e.—Front Brake Connections.

position, remove cotter C (Fig. 19c), and turn adjusting screw D until clearance between the drum and brake lining at this point is not more than $\frac{1}{32}$ inch, then replace cotter and adjust lower half of band by backing

up nuts *E* and *F* until $\frac{1}{32}$ inch clearance is obtained at this point—then lock these two nuts in place and proceed with upper half of band by backing off nut *G* until same ($\frac{1}{32}$ inch) clearance is obtained. After this last adjustment is made be sure that nut *G* is properly seated in groove in fitting, as this locks the adjustment.

Second, when these adjustments are complete there should be $\frac{1}{32}$ inch maximum clearance all around the drum; if not, readjust until this result is obtained.

When relining brake bands, the wheel must be removed and the brake band or bands detached and cleaned. The rivets holding the old lining should be cut and punched out. The new lining is then selected, and measured for length, width, and thickness from the brake band; or the repairman may refer to a brake-lining chart.

On small light brakes the lining is usually attached to the band with split rivets, the rivets being driven from the outside of the band through the lining, and the points spread and pounded below the surface. Care must be taken to see that the lining fits the band so that it does not draw. On heavier brakes, tubular or solid copper rivets should be used, with the heads countersunk in the lining and swollen on the outside of the band.

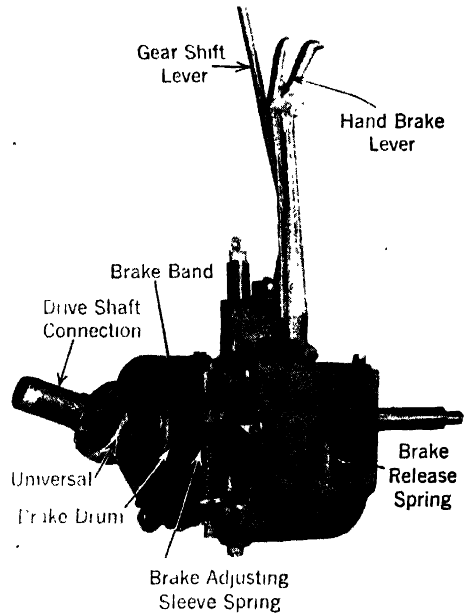


FIG. 19*f*.—Parking Brake on Drive Shaft.

When a car is descending a long, steep hill, the brakes, if depended upon alone to check the speed of the car, are likely to heat excessively, and the brake linings will be subjected to considerable wear. This severe use of the brakes can be relieved materially by using the engine as a brake. To do this, shift into second or even low speed just as the car starts to descend the hill, engage the clutch, and close the throttle. This will allow the motion of the car to drive the engine. The engine becomes the brake with the throttle closed, owing to the fact that the pistons are

operating against compression; this, together with the friction of the operating parts of the engine, imposes a powerful braking effect on the car.

There are a number of things that have a tendency to cause the brakes on any car to squeak. In cases where the trouble refuses to yield to ordinary treatment, a small portion of the lining can be removed from the rear of the band at the brake anchor.

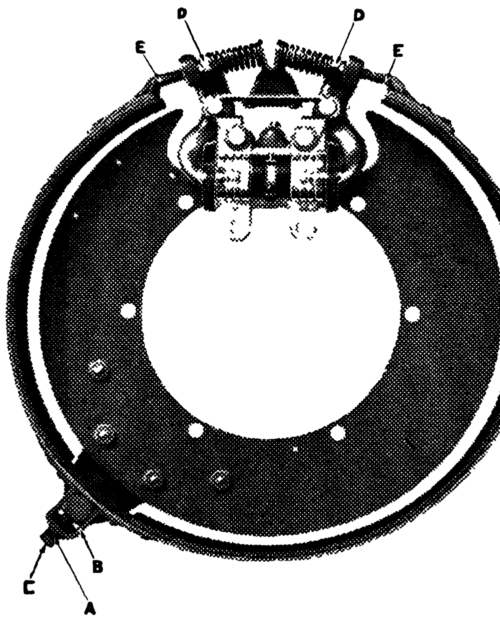


FIG. 19*g*.—Hydraulic-brake Adjustments.

A Cotter pin B Anchor bracket
C Adjusting screw D Brake-band clip nut.
E. Brake-band clip.

Questions.

1. What tests should be made to determine whether the brakes need adjustment?
2. How will the driver know that the brakes need relining?
3. How are the brake bands relined?
4. What is the composition of brake lining?
5. How are old linings removed?
6. What are the two types of brakes?
7. How should they be used when descending a long grade?
8. How may overheating be prevented?
9. What is the purpose of a brake equalizer?

10. What causes squeaky brakes and how can this be remedied?
11. Explain how to operate brakes on a slippery pavement and keep the wheels from skidding.
12. If oil or grease is causing the brakes to slip, how should the bands be treated?
13. How may squeaky brakes be repaired?

Job No. 20

BLEEDING A HYDRAULIC BRAKE SYSTEM

References. Part Two, p. 367.

Operations Necessary to Perform the Job.

1. Fill supply tank with fluid.
2. Remove dust screw at wheel cylinder. (Bleed only one cylinder at a time.)
3. Put rubber tubing over bleeding connection.
4. Place other end of tubing in a glass jar.
5. Unscrew bleeder connection three-quarters of a turn.
6. Move pump handle up and down.
7. Tighten bleeder connection securely.
8. Refill supply tank.

Names of Parts to be Reviewed before Performing the Job.

Bleeder, connection, screw, tubing, wheel cylinders, pistons, master cylinder, brake pedal, supply tank, pump handle, liquid.

Description of Operations.

Fill the supply tank full of brake liquid, open the valve, and pump the system full. If there is still excess movement in the brake pedal, it is necessary to bleed the system.

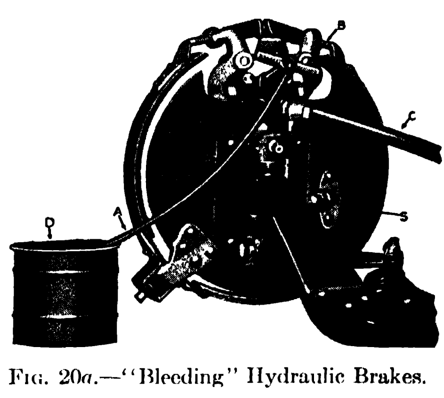


Fig. 20*a*.—"Bleeding" Hydraulic Brakes.

This may be done by removing the dust cap and placing a hose on the bleeder connection *B* as in Fig. 20*a*. Bleed each wheel separately. Move the pump handle of the supply tank up and down until the fluid from the tank forces out all air from the system. Pro-

ceed in the same manner for all other wheels. Refill the supply tank with liquid and replace the pump in a firm position.

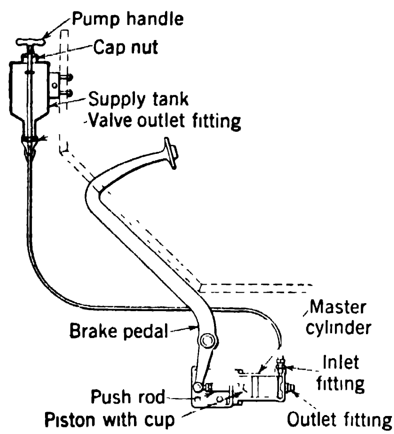


FIG. 20*b*.—Hydraulic-brake Pedal and Supply-tank Assembly.

To remove the air from the master cylinder, unscrew the handle *J*, and force the foot pedal down slowly by hand to the floor. This will force the liquid up in the supply tank, carrying with it all air that may be present in the master cylinder. After a few moments allow the pedal to return to its normal position. Now pump the system full of liquid by means of the pump in the supply tank. Close the supply-tank valve tightly before applying any pressure to the brake pedal.

Questions.

1. Why is it necessary to bleed the hydraulic-brake system?
2. When should this be done, and how?
3. How many wheels should be worked on at one time?
4. What solution is used in the hydraulic-brake system?

JOB No. 21

RELINING EMERGENCY BRAKE BAND ON MODEL "T" FORD CAR

Operations Necessary to Perform the Job.

1. Block up rear end.
2. Remove wheels.
3. Remove spring.
4. Remove brake shoes.
5. Remove old lining.
6. Replace new lining.
7. Install shoes.
8. Replace wheels.
9. Make necessary brake adjustments.

Description of Operations.

When relining brake shoes on Model "T" Ford cars the rear end of the car must be blocked up and the wheels and brake shoes removed.

The old lining must be removed, and new lining replaced properly. To install the new brake shoe, place it in position on the axle housing plate and insert the flange on the edge of the shoe behind the four steel clips, on housing plate. Line up with hub-brake cam and press the end of the band over the cam. The brake-control rods may now be adjusted in the manner described in Job No. 19.

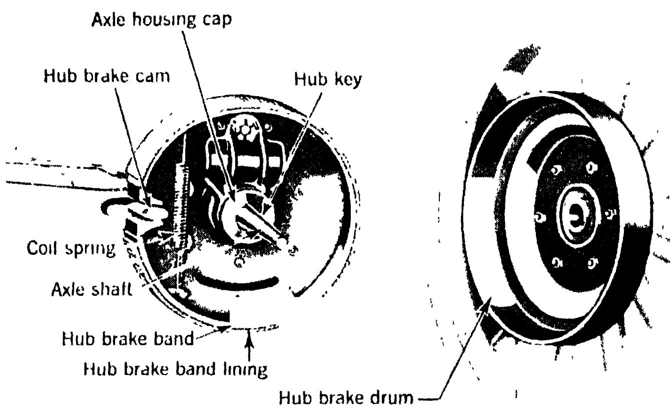


FIG. 21a.—The Ford Emergency Brake. (Model T.)

Questions.

1. When is it necessary to replace lining on brake bands of a Ford car?
2. What are the steps necessary to remove and replace brake lining on the brake bands of a Ford car?
3. What adjustments are necessary after relining brakes?

JOB NO. 22

ADJUSTING AND RELINING MODEL "T" FORD TRANSMISSION AND BRAKE BANDS

Operations Necessary to Perform the Job.

1. Remove transmission door cover.
2. Remove bands from drum.
3. Remove lining from bands.

4. Replace with new lining.
5. Re-install bands.
6. Make all necessary adjustments for correct application of power or brake.
7. Replace gasket and door cover on transmission case.

Description of Operations.

The slow-speed band may be tightened by loosening the lock nut at the right side of the transmission cover, and turning the adjusting screw

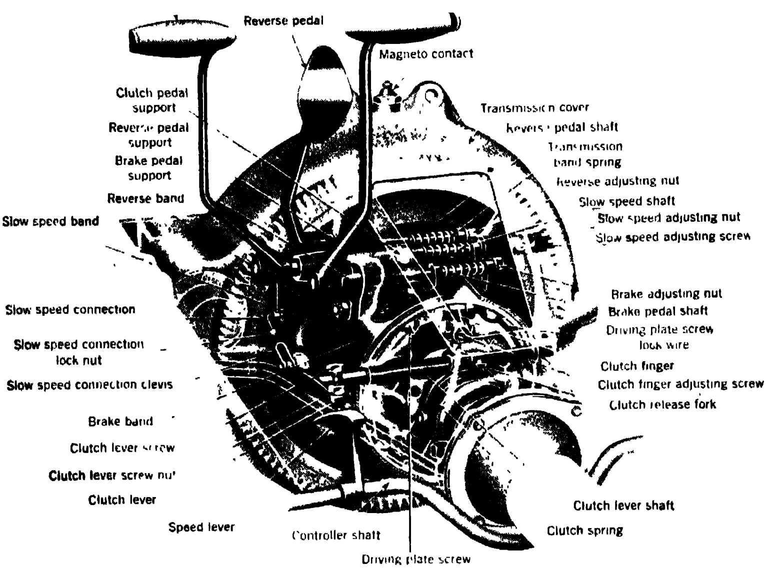


FIG. 22*a*.—Ford Transmission, showing Operation of Clutch. (Model T.)

(see Fig. 22*a*) to the right. To tighten the brake and reverse bands, remove the transmission door and turn the adjusting nuts on the shafts to the right. See that the bands do not drag on the drums when disengaged, as they exert a brake effect and tend to overheat the motor. However, the foot brake should be adjusted so that a sudden pressure will stop the car immediately or slide the rear wheels, in case of emergency. The bands, when worn to such an extent that they will not take hold properly, should be relined, so that they will engage smoothly without causing a jerky movement of the car. To remove the transmission

bands, remove the transmission cover door, remove the nuts and lock washers from the ends of the pedal shafts, unscrew the slow-speed adjustment, and remove the springs. *Extreme care should be exercised to prevent dropping any parts into the transmission.*

The reverse pedal and brake pedal should then be withdrawn as far as possible and the detachable ears of the bands removed. To remove the ear, simply insert a tool (a screw driver with the end bent over approximately ¼ inch) through the end of the ear into a hole in the end of the

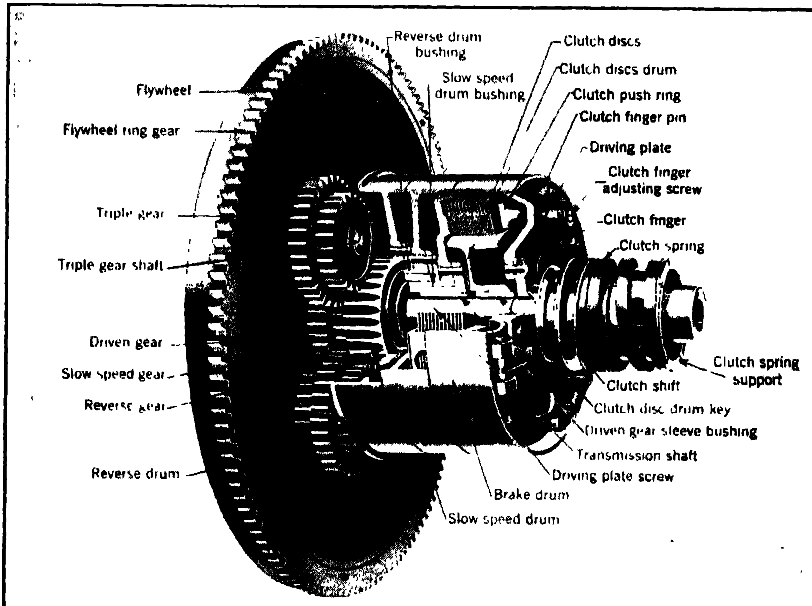


FIG. 22b.—Ford Transmission, showing Gears in Mesh. (Model T.)

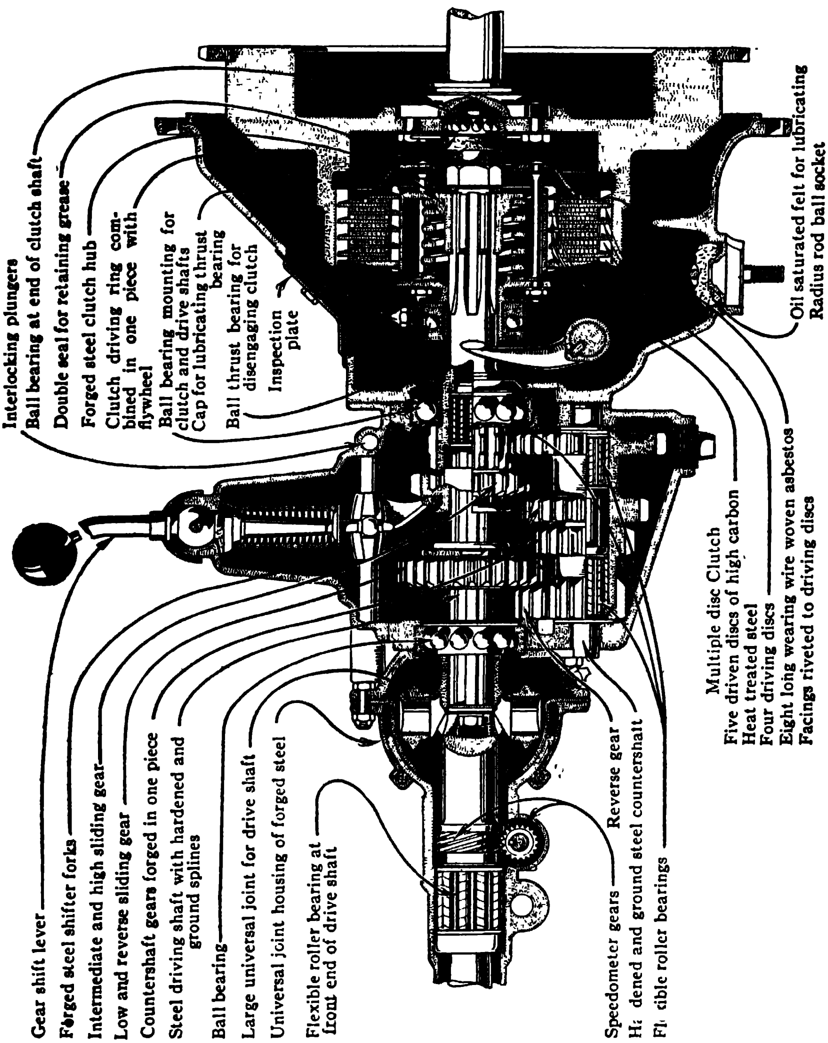
transmission band, and lift up on the tool, forcing the band down and the ear back. The bands may then be withdrawn from the right side, permitting them to follow close to the cover to prevent their being distorted.

To replace the bands, insert the plain end in the right side of the transmission cover, forcing the band around until it is possible to reach the hole with the hooked tool. When the end of the band has been pulled around, the ear may be slipped over the studs and forced forward into the locked position, with the hooked tool if necessary.

When reassembling the parts the reverse band should be replaced

first, the brake band second, and the slow-speed band last. The band ears should then be replaced.

The slow-speed adjusting screw, reverse and pedal shafts, and



22c.—Ford Transmission (Model A.)

transmission band springs are then reassembled, and the ears drawn into place, being held against the compression of the spring with the hooked tool.

The lock washers and nuts may then be replaced and the bands adjusted in the usual way.

Questions.

1. How will you know when the transmission bands should be replaced?
2. How may we gain access to the Ford transmission bands?
3. How are the bands removed?
4. Explain how the old lining on the transmission bands is removed and new lining replaced.
5. How is each of the bands adjusted?

Job No. 23

INSTALLING NEW UNIVERSAL OR PARTS

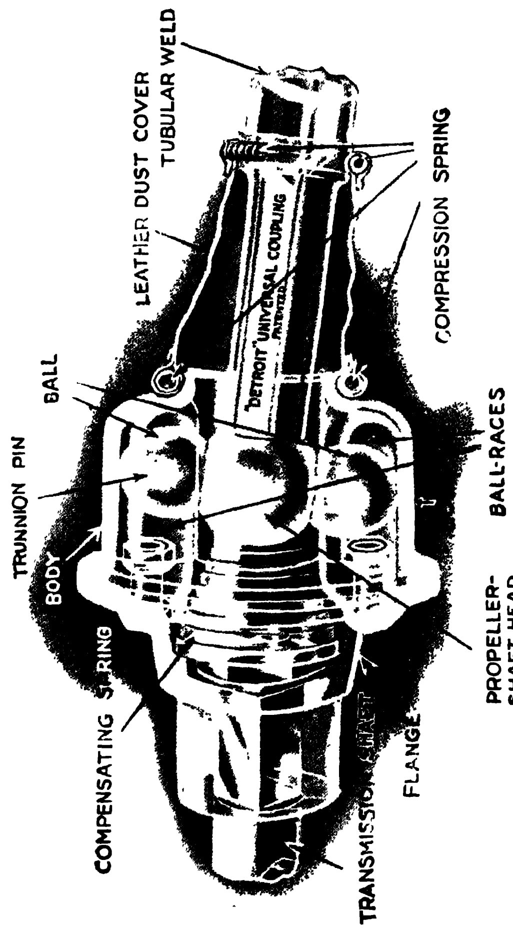


Fig. 23a.—Propeller Shaft and Universal Joint. (Paige.)

Operations Necessary to Perform the Job.

1. Disconnect drive shaft.
2. Remove universal.

3. Clean and inspect for broken or worn parts.
4. Replace either whole universal or parts, as needed.
5. Pack with grease and reassemble.

FIG. 23b.—Spicer Universal Joint Disassembled.

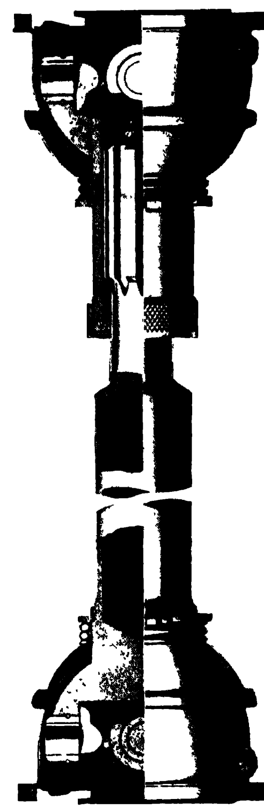


FIG. 23c.—Universal Joint Assembly and Shaft.

Description of Operations.

As the motive power is not transmitted through the transmission to the rear axle in a straight line, it is necessary that universal joints be

installed. The angularity of the axle propelling shaft is subject to change by the spring action and there is also a distortion of the frame while the car is in operation, thus making a universal connection necessary. The universal joint, as shown in Fig. 23*a*, includes a slip connection which allows for any variation in the overall length due to the spring action. This slip connection consists of a grooved socket which receives the splined end of the shaft and provides for the forward and backward thrust.

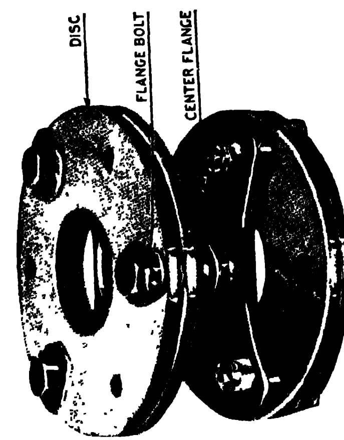


FIG. 23*d*.—Flexible-disk Universal Joint.

To install a new universal joint, remove all parts necessary to permit the removal of the old universal joint. Disassemble the universal (Fig. 23*b*), and inspect for worn or broken parts. Install new parts or a complete joint as may be necessary. Replace the universal and pack it with a heavy grease, making sure that the grease-retaining device is in the proper place.

The propeller shaft with a universal joint serves as a driving mechanism between the transmission main shaft and the rear-axle pinion shaft. The rear axle is allowed by the springs to move up and down relative to the frame which carries the transmission, so that the propeller shaft must transmit the power at constantly varying angles. The function of the universal joint is to provide this necessary flexibility.

Care of the Universal Joints.

Owing to the fact that the universal joints not only transmit the full power of the engine, but at the same time allow for the constant up and down movement of the rear axle and frame, their share of the work of driving the car is very important and consequently they should regularly receive what little attention they require in the way of lubrication.

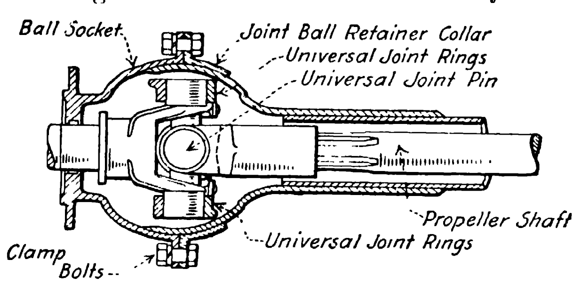


FIG. 23*c*.—Universal Joint. (Chevrolet).

Every 2000 or 3000 miles unscrew the plugs in the outer casing of the joints, and by pushing the car cause the joints to turn so that the holes will be at the bottom, and allow the dirty lubricant to drain out. Force a little kerosene into the holes to flush out as much of the old grease as possible, and then with the holes at the top fill the cases with light cup grease or non-flowing oil.

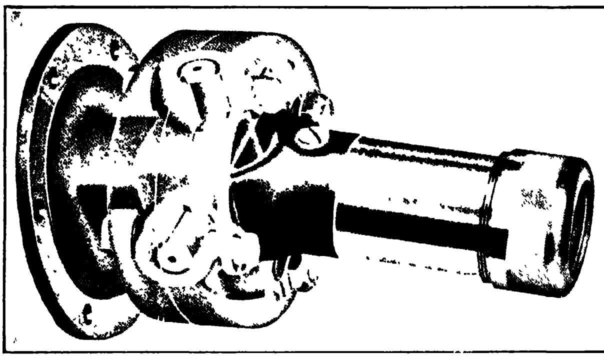


Fig. 23*f*.—Universal Joint. (Stutz)

Questions.

1. What types of universal joints are commonly used?
2. What schemes are used for lubrication?
3. How may the universal on the drive shaft be removed?
4. Why are universal joints needed?
5. What provision is made on most universal joints to protect them from dust and to retain the lubricant?
6. How is the lubricant put into the housing?
7. How often is lubrication necessary?
8. Which would be better, oil or grease?
9. What would be the effect of running with the universal joint dry?
10. What provision is generally made to permit the drive shaft to change its length slightly when the springs are deflected?
11. If this joint is allowed to become dry, what will be the effect upon the bearings in the back of the transmission case?

Job No. 21

LUBRICATING REAR AXLE

References.—Part Two, pp. 319 to 354.

Operations Necessary to Perform the Job.

1. Remove plug.
2. Insert nozzle of grease gun.

3. Fill housing with proper lubricant to required amount.
4. Whenever necessary, remove old grease before filling.
5. Wash out housing and fill as above.
6. Replace plug and clean housing.

Description of Operations.

To lubricate the rear axle, remove the filler plug and fill the axle housing with new grease or gear oil. This lubricant is forced into the axle housing through the filler hole by the use of a grease gun or pump. Every 2000 or 3000 miles, refill with the proper amount of new grease. When washing the housing, drain all old oil out and force kerosene in with an oil gun. Let all kerosene drain out before filling with grease. Rear axles should be filled to the level of the filler plug.

Questions.

1. How may the amount and condition of old lubricants in the rear axle be determined?
2. What kind and how much lubricant should be used in the rear axles?
3. How should the outer bearing in the rear axle be lubricated?
4. Where are grease retainers placed and why are they necessary?

Job No. 25

ADJUSTING A CLUTCH

References.—Part Two, p. 371-5.

Operations Necessary to Perform the Job.

1. Remove parts as necessary to permit free access to spring-adjusting nut or nuts.
2. Adjust for "throw out," clutch brake, spring tension, and gradual application.
3. Replace parts.

Description of Operations.

Clutch adjustments consist of increasing and decreasing the tension of the spring or springs and also the distance the driven member is thrown out from the driving member.

When the clutch is known to be in a good condition and it still slips or grabs, the spring or springs which hold the clutch must be adjusted. This may be done by removing the parts necessary to permit the mechanic to have free access to the spring adjustments. If one spring is used, turn the adjusting nut to the right or left, depending upon the

tension desired. If more than one spring is used, turn the nuts until the pressure is equal on all. After the adjustment is made the car should be tried out on inclines or the rear end blocked up and a load applied to the brakes. Do not tighten the adjustment more than is necessary to carry the maximum load.

Whenever the members of a clutch do not thoroughly disengage when the foot pedal is pressed to its extremity, the clutch throw-out adjustments are at fault. This can be remedied by shortening the control as in Fig. 25*a* or by replacing the throw-out collar or yoke.

Instructions for Adjusting a Borg and Beck Clutch.

To tighten the clutch, push down the clutch pedal with the foot lever (see Figs. 25*a* and 25*b*) and, after loosening slot bolts *AA*, shift the bolts

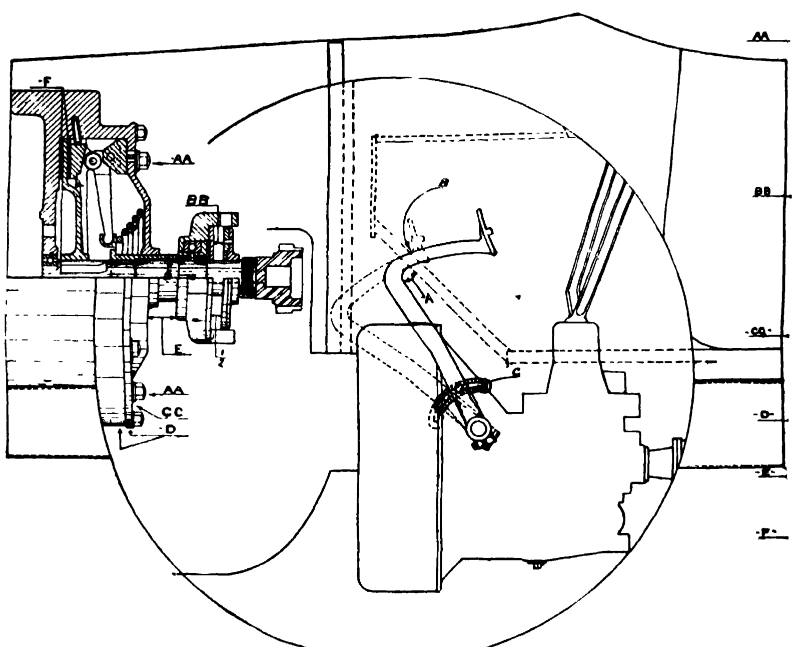


Fig. 25*a*.—Dry-plate Clutch Pedal Adjustment.

clockwise about ½ inch. Now let in the clutch, and, if the opening at *BB* is less than ½ inch, throw it out again and tap the slot bolts backward or anti-clockwise far enough to open the space at *BB* to a full ½ inch, or according to specifications in the Instruction Manuals.

The adjustments *AA* also adjust the foot pedal. When the clutch

slips it is usually due to the clutch pedal hanging up on the inner side of the foot board at *A* (Fig. 25*a*). When adjusting the clutch see that at least ½ inch clearance is left between the pedal and the foot board.

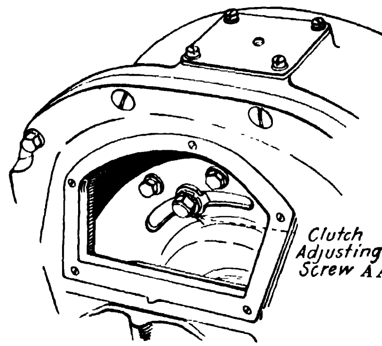


FIG. 25*b*.—Clutch-adjustment Screw.

The adjustment at *AA* must be used to increase or decrease this *BB* space. When the clutch is in, if the space between these brake faces is less than ½ inch, the throw-out movement will be too short for a clean release. Space *BB* should be ½ inch when the clutch is in, and there should be ½ inch clearance at *A*. The clutch pedal should clear the toe board about ¾ inch at *B*. If the space at *BB* is more than ½ inch, the clutch pedal will rest on the toe board at *B*, and will not allow these brake faces at *BB* to come together, the result being that the clutch will spin and the gears will clash when they are being shifted.

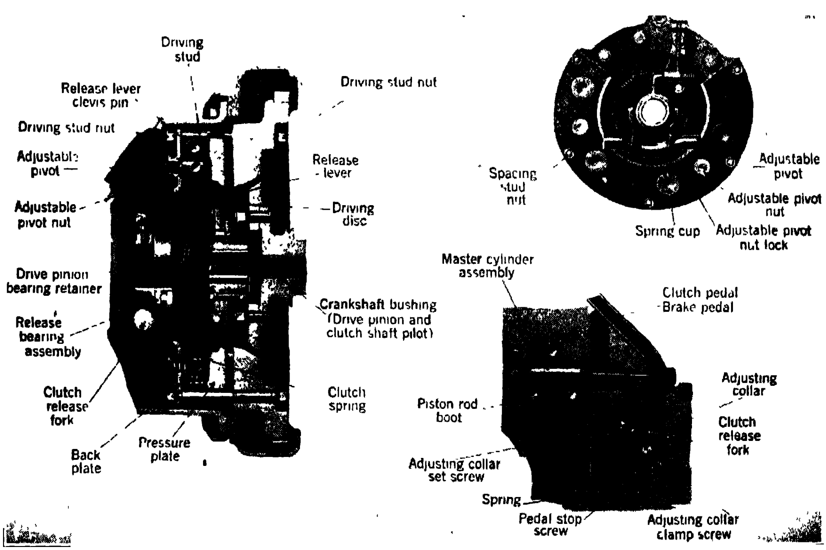


FIG. 25*c*.—Section of a Plate Clutch.

When bolts *AA* reach the last end of the cover slots, as the result of repeated adjustments, screw them out of their mounting holes and set

them back into the repeat holes exposed near the first end of the slots, thus doubling the range of adjustment.

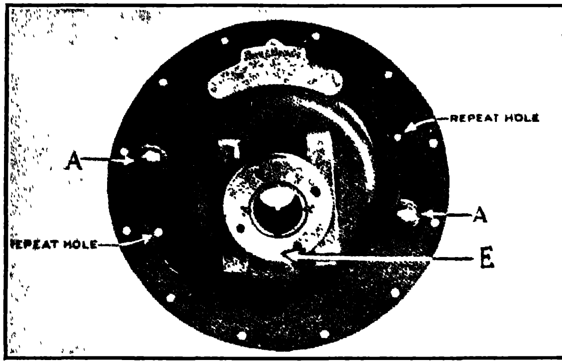


FIG. 25*d*.—Plate Clutch and Pedal Adjustment.

If necessary to get a proper clearance at *A*, set the pedal forward or backward at *C*.

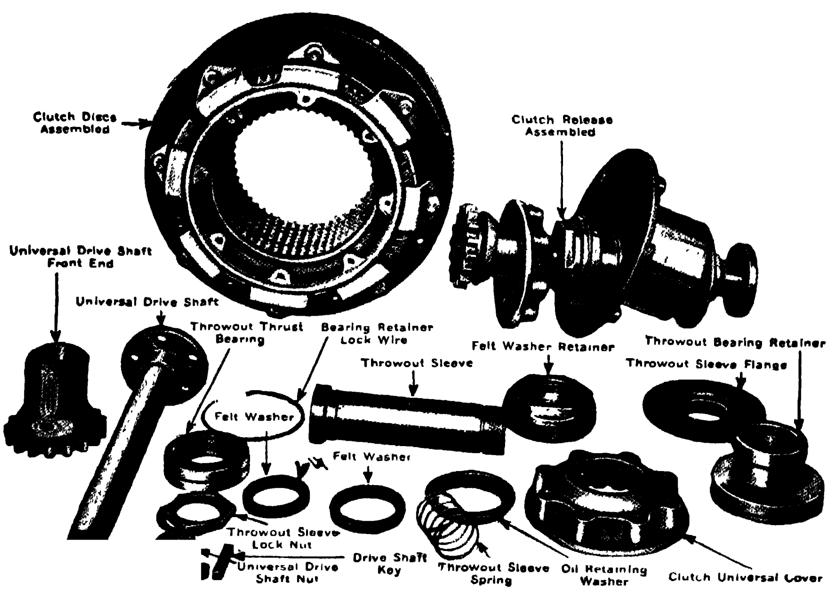


FIG. 25*c*.—Clutch-release Mechanism. (Marmon.)

If, for any reason, the clutch is to be taken apart, first punch remounting line-up marks on the cover and the casing, as the clutch will not work properly if the cover is shifted in remounting.

In taking the clutch apart, first press down the release pedal and "lock-out" the spring by placing a space block between the cover and throw-out yoke at *E*, as shown in Fig. 25*d*.

Always leave the asbestos rings loose in their working seats. Do not fasten them to the metal parts, and do not run the clutch in oil.

Positive engagement of the clutch is secured by means of great leverage, not by stiff springs.

The disassembled clutch shown in Fig. 25*e* is a multiple-disk clutch used on the Marmon car. It consists of two series of dry plates which are alternately connected with a casing attached to the flywheel and with a gear on the clutch shaft. The driving plates are faced with special friction material which makes contact with the hardened and ground steel driven plates.

The clutch plates are held in contact by the tension of eight coil springs. Pressure upon the left pedal compresses the springs and allows the plates to separate slightly by sliding endwise on their respective teeth. These teeth connect the driving plates to the flywheel casing and the driven plates to the clutch shaft gear.

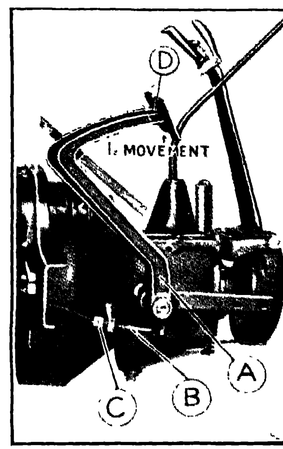


Fig. 25*f*.—Clutch-Pedal Adjustment.

Do not "ride" the clutch pedal– that is, hold the foot against it when driving steadily, as there is a possibility of keeping it partially out of engagement. See that the clutch pedal is properly adjusted in the engaged position.

When the clutch is in the fully engaged position, the pedal should depress 1 inch under light spring pressure before resistance of the heavy clutch springs is encountered.

If the pedal is brought against the floor board before the clutch is entirely engaged, full action of the clutch spring is not obtained, which will cause the clutch to slip.

A rod connecting the clutch pedal with the clutch release lever on the left of the clutch housing gives the necessary means for obtaining the correct adjustment for the clutch pedal. Lengthening the rod by means of the adjusting nut will increase the amount of travel under light pressure before disengaging.

No other change from the original adjustment will be required as the clutch surfaces are automatic in their compensation for wear.

For specific directions in making the adjustments for other types, refer to the manufacturer's instruction book.

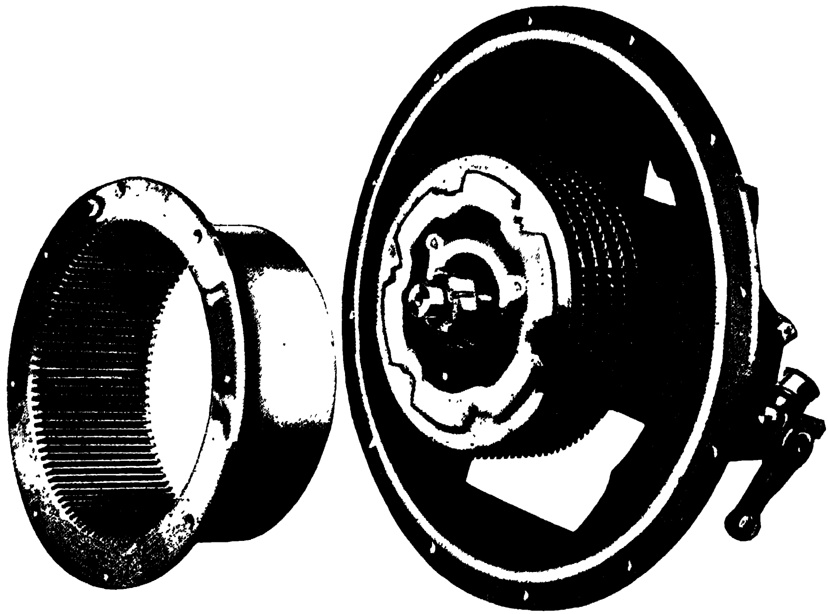


FIG. 25g.- Dry-disk Clutch Assembly.

Questions.

1. In what position should the throttle be when the clutch is held open?
2. Explain how the spring adjustments are made for each type of clutch.
3. How should the adjustment be tested?
4. Describe the construction of the multiple-disk clutch.
5. Describe the construction of the plate clutch.
6. Name a car using a multiple-disk clutch.
7. Why is a clutch brake necessary?
8. What kind of a clutch is used on a Model A Ford car?
9. What is the best position of the clutch when applying the brakes on a slippery pavement?

JOB NO. 26

INSTALLING NEW CLUTCH BEARINGS

References.—Part Two, p. 371-5.

Operations Necessary to Perform the Job.

1. Remove clutch and parts.
2. Remove clutch bearings.

3. Replace with new bearings.
4. Lubricate.
5. Make adjustments.
6. Replace all parts.

Description of Operations.

Clutch bearings become defective when the operator rides the clutch pedal while driving, when the lubrication has been insufficient, and after long usage. A new bearing is then necessary. The repairman should remove all parts necessary for taking out the old bearing and install the new bearing, making sure that the lubricating passages are clear. The parts should then be reassembled, the bearings lubricated, and the adjustments made according to the instructions in Job No. 25.

Questions.

1. How may one determine whether a new clutch bearing is needed?
2. After removing old bearings and replacing new bearings, what adjustments should be made?
3. What will be the result if a disk clutch is permitted to slip?
4. What is the purpose of the throw-out bearing?
5. Where is the pilot bearing located?

Job No. 27

TREATING CLUTCH LEATHER

Operations Necessary to Perform the Job.

1. Disengage clutch from flywheel.
2. Wash leather with kerosene.
3. Apply neat's-foot oil.
4. Re-engage in flywheel.

Description of Operations.

The pressure with which the clutch cone is held in engagement with the flywheel is varied by increasing or decreasing the tension of the clutch springs. These springs should be adjusted so that the clutch engages with sufficient force to prevent slipping and at the same time may be disengaged without undue pressure on the clutch pedal. Spring tension should be as light as possible without allowing the clutch to slip. If the car fails to move readily and the engine continues to turn over after pressure on the foot pedal has been released, the clutch is slipping. This may be caused by a worn clutch facing or by insufficient tension of the main springs. Should the clutch grab, thus causing a jerky start,

the clutch facing may be hard and dry. This condition can be relieved by disengaging the clutch from the wheel, washing the leather with kerosene, and redressing the surface. When this is done it should be followed by an application of neat's-foot oil. The use of neat's-foot oil prolongs the life of the leather.

Questions.

1. What are the indications that the clutch leather needs treatment?
2. What is a good method of treating clutch leather?
3. If the clutch leather is glazed, what treatment is necessary?
4. If the clutch leather is too dry, what treatment is necessary?
5. If the clutch leather is soft and oil-soaked, what treatment is necessary?

Job No. 28

REPAIRING A "SPINNING CLUTCH"

References. Part Two, p. 371-5.

Operations Necessary to Perform the Job.

1. Determine cause of clutch spinning.
2. If clutch brake is used, adjust to prevent spinning.
3. If dry pilot bearing is cause, lubricate same.
4. If clutch does not "throw out far enough," readjust "throw."

Description of Operations.

When the driver of an automobile experiences difficulty in shifting gears, caused by the gears not slacking their speed soon enough after the clutch has been disengaged, he has a "spinning clutch." To remove this trouble, first locate the cause. This may be a defective clutch brake, a dry bearing, or an improper adjustment of the "throw."

If the brake is out of adjustment, he should make the adjustment as previously described. If the brake facing is worn or oil soaked, it should be cleaned with kerosene or replaced with a new facing. If a dry or defective bearing is the cause, lubricate or replace the bearing. If the "throw" needs adjusting, make the adjustment according to instructions given in Job No. 25.

Questions.

1. What adjustments should be made if the "clutch spinning" is caused by the clutch not being thrown out far enough?
2. What adjustment must be made if the "clutch spinning" is due to the clutch brake?
3. If the "clutch spinning" is caused by dry bearings, what is needed?

Job No. 29

REPAIRING A "GRABBING CLUTCH"

References.—Part Two, p. 372-5.

Operations Necessary to Perform the Job.

1. Determine cause of trouble.
2. If a disk clutch, inspect disks for defects and repair same.
3. If clutch runs in oil, change oil, according to directions in manufacturer's manual.

Description of Operations.

If the oil in a wet clutch is too thin, or the spring tension is too strong, or if the expanding springs of a cone clutch are too weak, or the surface of the leather facing hard or dry, the clutch will engage suddenly or "grab." If "grabbing" is caused by the oil being too thin, drain out the oil and replace it with oil recommended by the manufacturer. If the springs are at fault, adjust or replace them according to the instructions already given.

In a dry single-plate clutch, "grabbing," which makes gear shifting difficult, comes from the failure of the clutch to release properly and to allow the driving disk on the stem gear shaft to come to rest. It may be due either to too tight an adjustment of the clutch or to the failure of the clutch-brake action.

A "grabbing" or "stuttering" clutch causes the car to jump as the clutch is let in and shows uneven gripping of the friction or driving disk by the asbestos friction rings. When repairing, take the clutch down and secure proper alignment of the stem gear shaft. If the "grabbing" comes from a warped drive disk caused by overheating from slipping, it will be necessary to replace the driving disk and friction rings.

At times "grabbing" in disk clutches may be caused by the accumulation of dirt or foreign matter on the asbestos friction rings and drive disks. To repair, wash out the clutch by cleaning it with kerosene. Do not fail to oil the clutch after using kerosene.

Questions.

1. What is meant by "grabbing" clutch?
2. If the clutch "grabs" because the spring tension is too great, what adjustments are necessary?
3. In case the disks are found to be rough, what treatment is necessary?
4. When "grabbing" in wet clutches is caused by oil being too thin, what should the repairman do to eliminate the trouble?

Job No. 30

REPAIRING A "SLIPPING CLUTCH"

Operations Necessary to Perform the Job.

1. Determine cause of slipping.
2. Tighten spring tension, if necessary.
3. Check clearance between toe board and clutch pedal.
4. Clean leather on cone clutches if oily, and apply fuller's earth.
5. If a wet disk clutch, change oil if necessary.

Description of Operations.

If the oil in a wet clutch is too thick or the spring tension insufficient, or if the facing becomes glazed, the clutch will slip on heavy loads. When the oil is found to be the cause of the trouble it should be changed.

If the spring adjustment is the cause of "slipping" the spring should be tightened, and if it is too weak a new spring should be installed.

If the leather facing on a cone clutch has become glazed, it should be treated as described in Job No. 27.

If the leather is too oily it should be cleaned and given an application of fuller's earth.

In a single-plate dry-disk clutch, slipping is a bad condition that may ruin friction rings, driving disk bearings, sleeve, in fact the whole clutch, if allowed to continue. It is usually caused by a continual pedal pressure on the underside of the floor board, which holds the clutch partially "out." The clutch pedal can be moved forward to clear the floor boards by means of the pedal adjuster. If the clutch still slips after the pedal clears the floor board, adjust the clutch by moving the two adjustment bolts as described in Job No. 25. If slipping comes from too loose an adjustment of the clutch, the same remedy will correct it.

To clean out the enclosed clutch in Fig. 25*b*, remove the adjusting screw *A* and pour in ½ pint of kerosene, replace screw *A*, start the engine, and let it run slowly for fifteen minutes. While the engine is running, slowly push the clutch pedal in and out a few times. This will allow the kerosene to wash off the driving disk. Remove the screw *A* and turn the engine over until *A* is at the bottom position. Now jack up the front of the car so that the front wheels will be in a higher position than the rear, and let the clutch drain over night before putting the car into operation again.

Questions.

1. If the spring tension is too weak, what adjustments should be made?
2. If the leather facing is oil soaked, how should it be treated?
3. In case the clutch continues to slip after being cleaned, what treatment may be applied?
4. If slipping in a disk clutch is caused by the oil being too thick, how may it be treated?
5. If changing oil does not stop the slipping of a clutch, what adjustments should be made?
6. What are the three most used types of clutches?
7. Name several cars using each type.

Job No. 31

REFACING DISK CLUTCHES

References.—Part Two, p. 371.

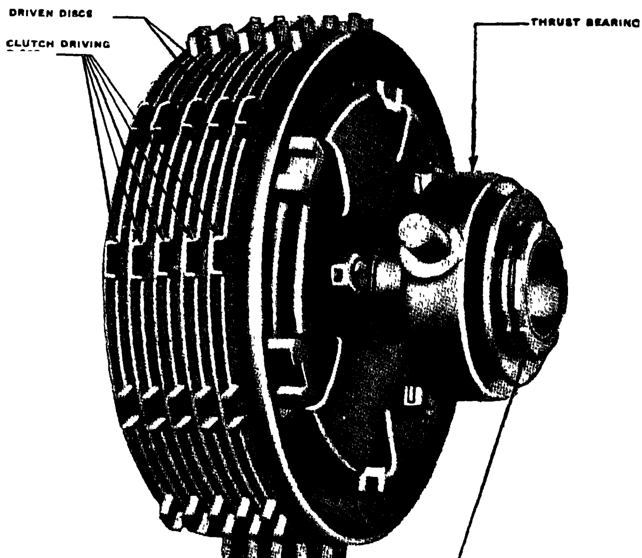


Fig. 31*a*.—Dry Plate Disk Clutch.

Operations Necessary to Perform the Job.

1. Remove all parts necessary to permit removal of clutch.
2. Remove clutch.
3. Remove disks and clean.
4. Cut rivets from facing and put on new facing.
5. Replace all parts and make necessary adjustments as in Job No. 25.

Description of Operations.

When a clutch begins to slip because of worn linings, it should be repaired at once. Continued running of the car under these conditions will soon cause sufficient wear to develop to injure the clutch mechanism.

Fig. 31*a* shows a clutch which consists of eleven alternating Raybestos-covered plates working against soft steel plates, five of which are keyed to the flywheel and six of which are keyed to the main driving shaft. When the clutch is thrown out, these disks are allowed to separate, the Raybestos-covered plates rotating with the flywheel and the steel plates remaining at rest on the transmission shaft.

When refacing the clutch disks, the clutch must be removed and disassembled. The rivets holding the facings are then cut and punched out. New facings are applied with tubular brass rivets. Care must be taken to see that both ends of the rivets are countersunk so as not to touch the soft metal disk. Now reassemble the clutch, replace all parts, and make adjustments.

Questions.

1. How will the driver know that the disks require new facings?
2. Explain how the old facing is removed and new facings installed.

Job No. 32

CHANGING CLUTCH OIL

References.—Part Two, p. 371-5.

Operations Necessary to Perform the Job.

1. Drain old oil from clutch.
2. Wash clutch with kerosene.
3. Lubricate with oil recommended for the make of clutch, or with cylinder oil and kerosene mixed.

Description of Operations.

When it becomes necessary to change the oil in a wet clutch, remove the drain and filler plugs. A container should be provided to receive the old oil.

After the old oil is drained out, replace the drain plug and put a pint of kerosene in the clutch case. Start the engine and continue to operate it for two or three minutes, at the same time throwing the clutch out and in intermittently. The drain plug should be removed once more to allow the kerosene to drain out. Now replace the drain plug and fill the clutch case with the specified amount of clutch oil (see manufac-

turer's specifications), or use an oil thinned with kerosene until the best operating results are obtained. Oil that is too thin will cause the clutch to "grab." In either case the oil may be adjusted to the right consistency.

Questions.

1. How may the clutch oil be removed and the case and disks washed?
2. Why is it best to use, in the clutch, the oil recommended by the manufacturers?
3. If the repairman cannot ascertain the lubricant recommended by the manufacturer, how should he prepare clutch lubricant?
4. How will the repairman know when the clutch oil is of the right consistency?

Job No. 33

LUBRICATING TRANSMISSION

References.— Part Two, p. 417.

Operations Necessary to Perform the Job.

1. Inspect transmission and lubricate as necessary.
2. If needed, drain out old oil and clean case.
3. Fill with correct amount of proper lubricant.

Description of Operations.

Most transmissions are of the selective sliding-gear type, and have three forward speeds and one reverse. When the gear-shifting lever is moved into the different positions, one of two sliding gears is moved into mesh with one of the gears on the countershaft. (See Fig. 44 in Part two.) The countershaft gears are of different sizes with respect to gear ratios and are constantly driven when the engine is running with the clutch engaged. The lowest forward speed is obtained when the largest sliding gear is in mesh with the smallest countershaft gear. The small gear revolves several times in turning the large gear once. This means that the crank shaft revolves several times in turning the transmission main shaft one revolution. The main shaft is connected to the rear axle through the universal joints and propeller shaft, and in this way the reduction directly affects the turning of the rear wheels. This same principle is involved in obtaining the intermediate speed except that the meshed gears are more nearly the same size. When in high speed, the

transmission main shaft is directly connected to the drive pinion and there is no speed reduction.

In reversing, one of the sliding gears is meshed with an idler gear which is in constant mesh with one of the countershaft gears.

Beyond careful handling in the matter of gear shifting, the only care the transmission requires is replenishing and changing the lubricant at specific intervals. In shifting gears and under ordinary running conditions, minute particles of metal will be worn off the gears and become mixed with the oil, so that unless the oil is changed occasionally the gritty lubricant will cause excessive wear of the bearings.

Every 2000 to 5000 miles, the transmission gear-case cover should be removed and the quantity and quality of the lubricant inspected. If the quantity is insufficient, add enough suitable lubricant (see manufacturer's specifications) to cover the lowest shaft. The repairman should be able to tell when the old lubricant has lost its efficiency by rubbing the oil between his fingers. If the oil feels gritty and dead, the drain plug should be removed, the old oil drained out, the case washed with kerosene, and new oil put in.

Questions.

1. What will often be found to have settled in the bottom of the transmission case?
2. What is the cause of these particles?
3. If they should roll up between the gears, what may be the result?
4. What will result if they are carried into a ball or roller bearing?
5. If all the parts of the transmission are washed carefully until clean and dry, and the case then filled with clean oil or grease, will it retain its pale-yellow color or will it soon become black? Why?
6. Which will be better as a lubricant for the transmission, stiff grease, soft grease, or a gear oil?
7. What is the objection to stiff grease?
8. How deep is it necessary to have the oil in a transmission case?
9. What would be the result of having the case filled too full?
10. How often do most manufacturers recommend that the transmission oil be changed?
11. What provision is generally made for draining the old oil?
12. Explain how kerosene should be used to insure that all the oil and all the small metal particles will be washed out.
13. If a strong horseshoe magnet were dipped in the bottom of the dirty oil, and then shaken gently in a pail of gasoline, what would probably be found attached to it?
14. If, when the cover has been removed from the gear box, the corners of the sliding gears are examined, in what condition will they be found?
15. Can this be avoided to any extent by a skillful driver?

Job No. 34

OVERHAULING TRANSMISSION

References.—Part Two, p. 375.

Operations Necessary to Perform the Job.

1. Remove transmission gear case from car.
2. Drain out old oil.
3. Clean case and parts.
4. Inspect gears for wear or broken parts.
5. Replace or repair as necessary.
6. Inspect bearings. If worn, replace same.
7. Reassemble, lubricate and replace on chassis.

Names of Parts and Operations to be Reviewed before Performing the Job.

Parts.—Transmission case, cover, clutch gear, clutch-gear bearing, bearing retainer, countershaft, front bearing, front-bearing bushing, front-bearing retainer, rear-bearing retainer, drive gear, second-speed gear, low-speed gear, reverse gear, reverse-idler gear, reverse-idler-gear shaft, reverse-idler gear bushing, transmission shaft, shaft-pilot bearing, shaft-pilot-bearing bushing, shaft rear bearing and shaft rear-bearing retainer, second and high sliding gear, low and reverse-sliding gear, high-gear shift fork, low-gear shift fork, high-gear shift bar, low-gear shift bar, gear-shift bar selector, gear-shift lever shaft, low-gear shift, connecting-rod, high-gear shift connecting-rod, gear-shift lever, gear-shift housing, propeller-shaft, propeller-shaft front universal-joint, propeller-shaft rear universal-joint, propeller-shaft front bearing, transmission-shaft universal-joint flange, universal-joint flange yoke, slip yoke, plain yoke, center cross, bearing bushing, pin, inner casing, outer casing, casing packing, casing nut, trunnion, and trunnion block.

Operations.—Shifting gears, aligning shafts.

Description of Operations.

The transmission varies the ratio of the number of revolutions of the engine to the number of revolutions of the wheels, thus giving the engine a greater or lesser leverage to help it perform the work of propelling the car. It consists of a series of fixed gears on the countershaft with which may be meshed a series of sliding gears on the main shaft. The engage-

ment of gears of different sizes produces the desired changes in speed and pulling power. The transmission shown in Fig. 34*a* has three speeds forward, the highest being direct with no reduction in the transmission, and one reverse speed. Reverse is obtained by introducing an extra gear or idler between the proper main and countershaft gears.

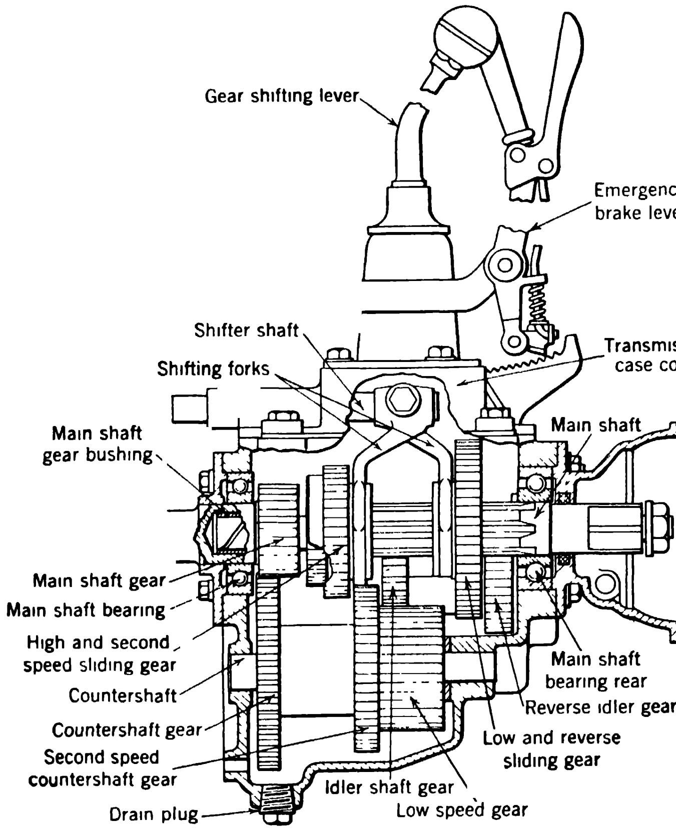


FIG. 34*a*. –Assembled Transmission.

To give a transmission a complete overhauling, remove the transmission from the car and take off the transmission-case cover. Thoroughly wash the case both inside and out and inspect it for cracks, injured gears, bearings, and sprung shafts. After noting the defects disassemble the transmission as per instructions given in the manufacturer's manual.

When disassembled, inspect each part separately. If the case is found to be cracked, it should be replaced with a new case or sent to a

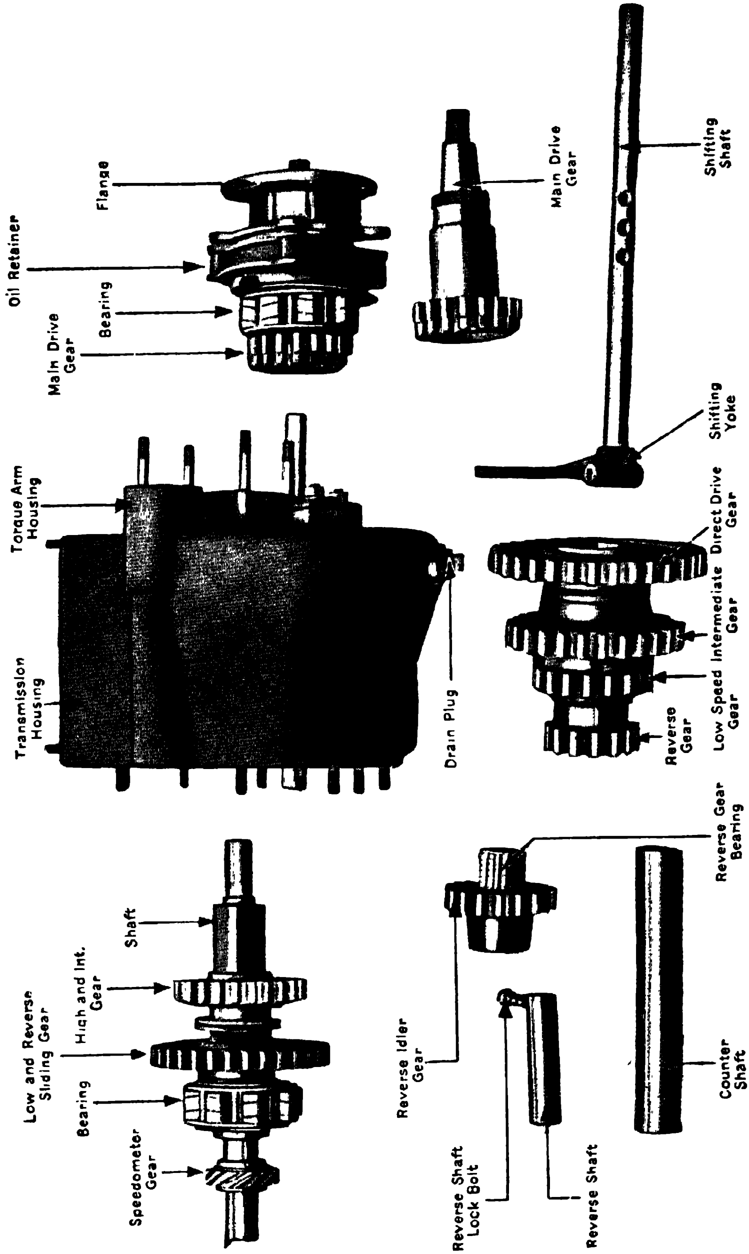


FIG. 34b.—Sliding Gear Transmission Disassembled. (Marmon.)

welder to be welded. If the bolt holes are worn they should be trued up and rethreaded for oversized bolts.

If the gear teeth are slightly worn and battered, the burrs may be ground off with an emery stone. Where the countershaft gears are

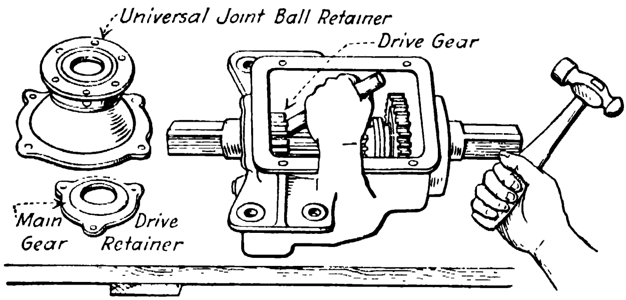


Fig. 34c.—Disassembling Transmission

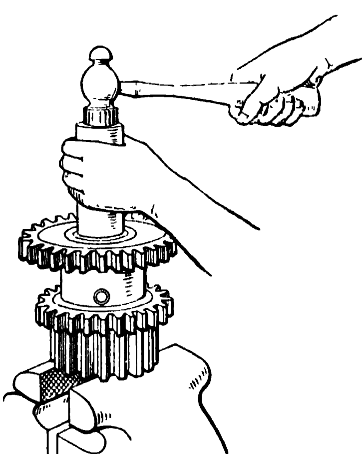


Fig. 34d.—Disassembling Countershaft.

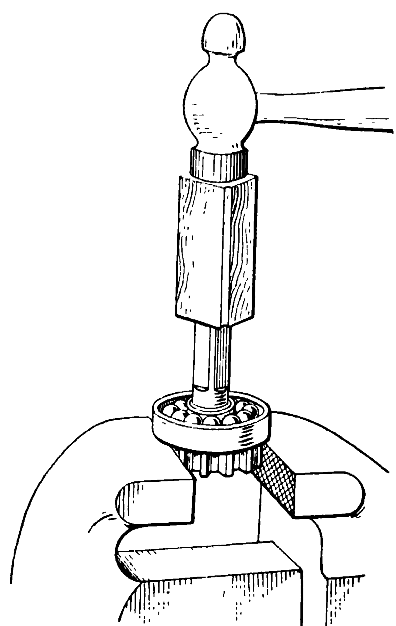


Fig. 34e.—Removing Bearing from Main Shaft Clutch Gear.

badly worn, the gears may be forced off in an arbor press and new gears installed. If the keys of these gears are worn, new ones should be used. If the countershaft is sprung, it should be replaced with a new shaft. If

the bearings show wear, they should be replaced with new bearings. If the spline shaft or sliding gears are worn, they should be replaced

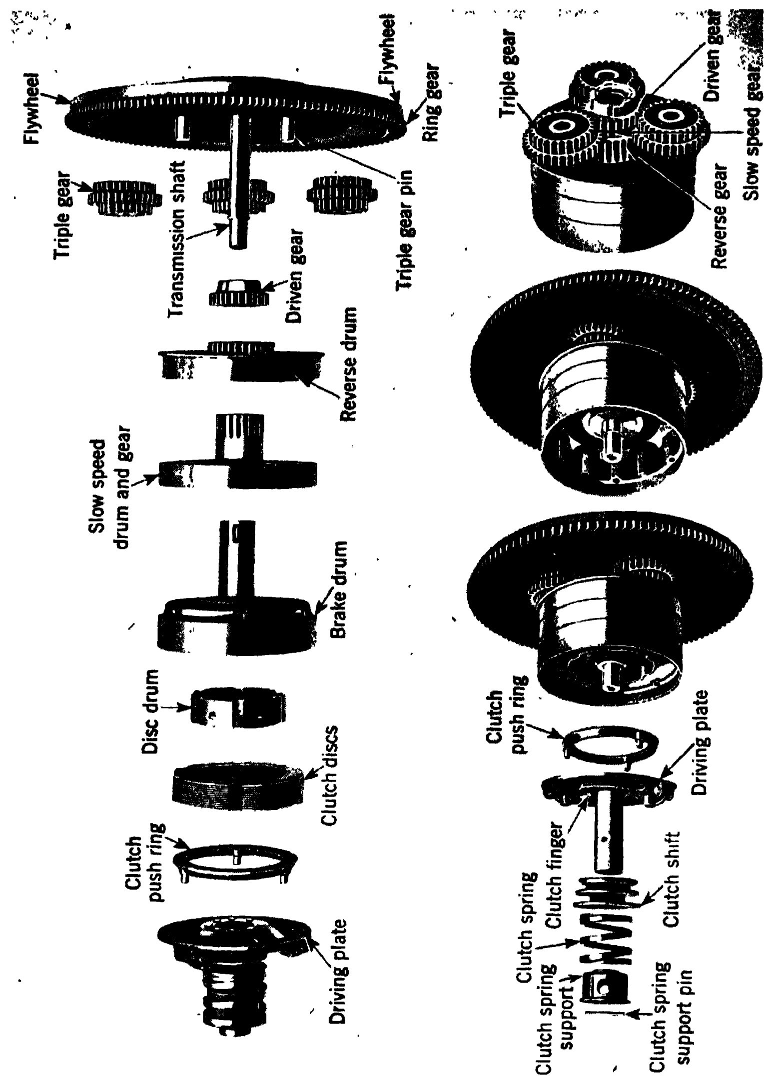


FIG. 34f.—Ford Transmission Parts in Their Relative Assembling Positions. (Model T.)

with new parts. If the teeth are slightly worn or battered, they may be dressed on an emery stone; if much worn, the gears should be replaced. If the idler gear or shaft is worn, replace it with a new part. If the shift-

ing forks are bent, they may be straightened; if worn, they should be replaced. If the forks are loose on their shaft, retighten them. If the shifting shaft locking devices are loose, they should be readjusted; if worn, they should be replaced. The parts should then be assembled and replaced on the car, the control rods connected and adjusted to proper throw, the transmission lubricated according to previous instructions, and the gasket cover replaced.

Questions.

1. How many speeds forward are generally provided in the transmission of a passenger car?
2. How are the different sets of gears brought into mesh?
3. What shape is the shaft upon which they slide?
4. From what material are the gears generally made?
5. Are the teeth hardened all the way through or only on the surface?
6. Can they be cut readily with a file?
7. When gears are clashed badly what happens to the corners of the teeth?
8. What will the broken particles do to gear teeth or bearings if they get into them?
9. What kind of lubricant is used in the transmission?
10. If the transmission is supported by the frame, on how many points is it generally suspended?
11. Are the shafts in Fig. 34*a* supported in plain bearings, ball bearings, or roller bearings. In Fig. 34*b*?
12. From what metals are transmission cases made?
13. When the case is of aluminum are the outer races of the bearings generally supported by the aluminum directly or by malleable retainers?
14. What provision is made to prevent the oil or grease from leaking out along the shafts and to keep the dust and dirt out?
15. What devices are provided to shift the gears into the different positions?
16. What devices are provided to hold the gears in position after they have been shifted?
17. What provision, if any, is made to prevent any other gears from shifting when one pair is in mesh?
18. If two different speeds could be engaged at the same time what would happen when the clutch was engaged?
19. In Fig. 34*a* what type of bearing is used to support the spline shaft? How many?
20. What type of bearing is used to support the main drive shaft? How many?
21. What type of bearing supports the front end of the spline shaft?
22. What type of bearing supports the countershaft? How many?
23. Are the gears keyed to the countershaft or are they free to turn?
24. Can they be pulled easily?

25. How can they be pulled?
26. When a ball bearing is to be pulled off a shaft, should the pressure be applied to the inner or the outer race? Why?
27. If the race is tight on the shaft, is it advisable to strike it hard with a punch in an effort to move it?
28. When a race is to be applied to a shaft, should it be a driving fit or a light tapping fit?
29. What will be the result if it is forced on when too tight a fit?
30. What will be the result if the race is too loose a fit on the shaft?

Job No. 35

REPAIRING "FLAT TIRES"

References.—Part Two, p. 495.

Operations Necessary to Perform the Job.

1. Remove rim with tire from wheel.
2. Remove tire from rim.
3. Remove inner tube.
4. Inspect casing for cause of puncture or blow-out.
5. Remove all foreign substances.
6. Insert blow-out patch if necessary.
7. Dust soapstone in casing.
8. Partially inflate good inner tube.
9. Install inner tube in casing.
10. Install casing on rim.
11. Inflate to proper pressure.
12. Install tire and rim on wheel.

Names of Materials and Tools to be Reviewed before Performing the Job.

Material.—Soapstone, blow-out patch.

Tools.—Tire irons, jack, pump, pliers, tire gauge, wrench.

Description of Operations.

The principal reason for insufficient tire mileage is improper inflation. The high-pressure tires should be kept inflated to their proper pressure; under-inflation will cause the side walls to break. The balloon or low-pressure tires will also deteriorate from improper inflation. Because of their wide road contact, uneven wear and bruises will result. The principal cause of wear on the treads of the front tires is misalignment

of the front wheels. If the wheels are not aligned they will, in addition to their rolling motion, scrape the tires slightly sidewise on the surface of the road as they revolve. This friction will wear off the tread of the tire in a very short time. Full instructions for proper alignment of the front wheels will be found in Job No. 8. on Wheel Alignment. The brakes should be adjusted so that they will be properly applied. If one brake sets before the other the tendency will be for the wheel to slide, thereby wearing off the treads of the tires. Even if the brakes are adjusted evenly, they should be applied carefully, otherwise even though they are not set with such force as to cause the wheels to slide, there will be a needless strain on the fabric of the tires.

The driver should prepare to stop at a sufficient distance to enable him to bring the car slowly and evenly to a standstill. For the same reason the clutch should be applied very gently when the car is started or when the gears are shifted. Jerking the car with the clutch not only brings needless strain on the mechanism, but spins the rear wheels slightly and wears off the tires. It is also important to turn corners slowly so that the tires will not have an excessive side strain.

If demountable rims are not applied evenly to the wheels, the effect will be precisely the same as though the wheels were out of alignment. When the rim is placed on the wheel the hole for the valve stem should be at the top. The tire can then be lifted up so that the valve stem will drop into the hole and the rim will fall easily to its place. Care should be taken to see that there is no mud on the wheel so that the rim will seat properly. After the wheel is in place, the lug on the opposite side from the valve stem should be tightened first. It should not be drawn so tight that it will distort the outer rim, but merely given sufficient tension to hold the rim firmly against its seat on the back side of the wheel. Next tighten the lugs on either side of the valve stem to the same tension. Now rotate the wheel to make sure that the rim is true. If the side opposite the valve stem is too far in, it can be brought out by loosening the lug and tightening the two lugs next to the valve. If it is too far out, loosen the lugs next to the valve and tighten the lug opposite. In this way the rim can be seated so that it will run true when the wheel revolves. After truing the wheel up in this way, tighten the other lugs, screwing them both up equally until they have the same amount of tension as the first three. Test the wheel again by revolving, to make sure that these two lugs are properly seated, and if they are, work entirely around the wheel, tightening each lug a little at a time until all of them are set solidly. The lugs should be tried occasionally to make sure that they are tight. If they are allowed to loosen up they will wear and cause a squeak to develop.

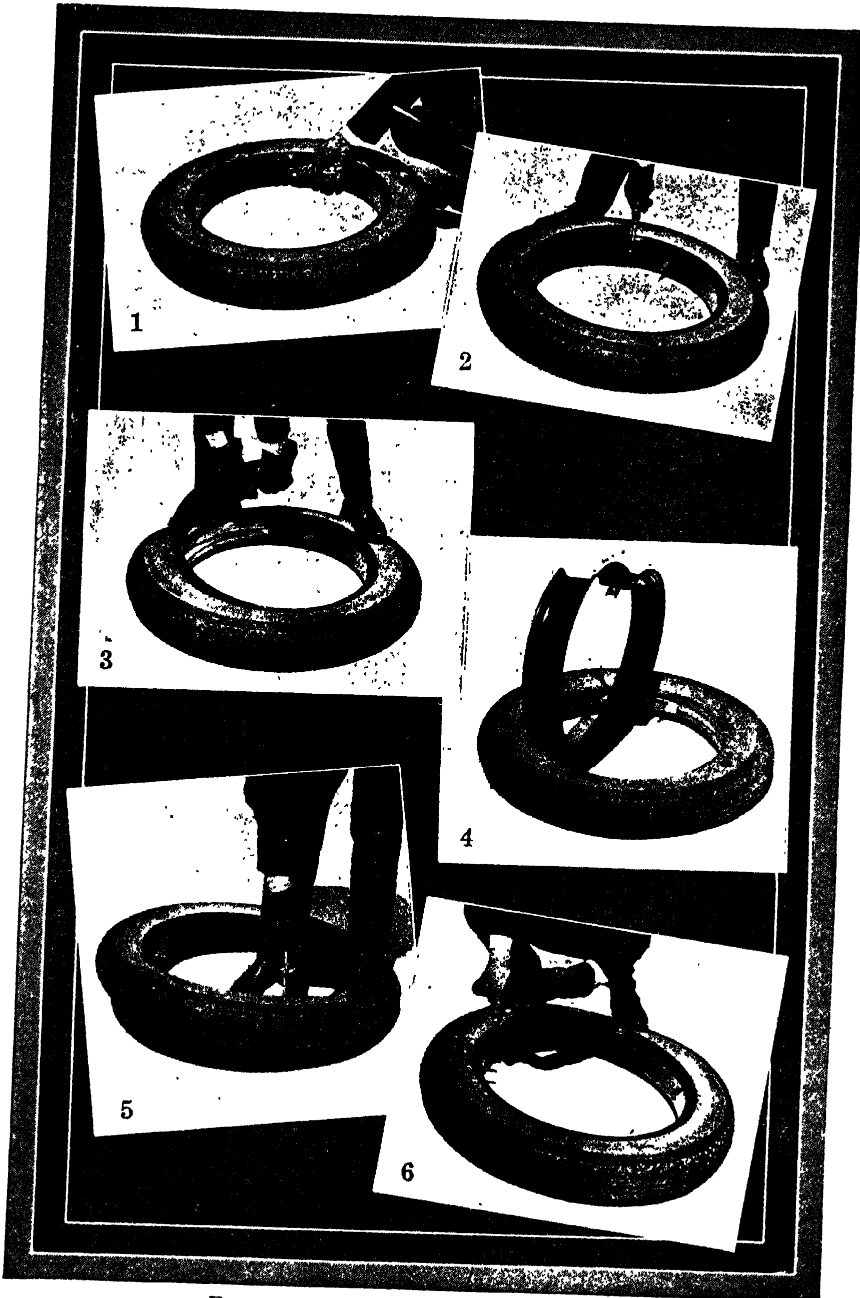


FIG. 35a.—Removing and Applying Rims.

In case a tire becomes flat, apply a pump and attempt to pump up the tire. If the tire settles after the pump has been removed, inspect the valve-stem core for a leak. If the core leaks, work the valve core in and out or screw it into place more securely. If this treatment fails, replace the valve core. If the valve does not leak, jack up the wheel, remove the rim, deflate the tire, remove the inner tube, and inspect the casing both inside and out for grit or other sharp substance. At the same time inspect the casing for holes or weak spots. If either is found insert a blow-out patch. Partly inflate a good tube, place it inside of the casing, remount the casing on the rim, inflate the tire to the correct pressure, and install the rim on the wheel.

When replacing the rim on the wheel, the tire should be fully inflated. Insert the valve stem in the hole in the felloe and push the lower edge of the rim on the wheel with the foot. Make certain that the driving lugs on the inner circumference of the rim rest between the lugs on the felloe band. Replace the wedges opposite the valve stem first, drawing them up evenly but not to their final position, and then replace the remainder of the wedges and draw the bolts up evenly until all are tight.

Questions.

1. What attention should be given to a rim if it begins to rust?
2. What is the average pressure per cross inch for balloon tires?
3. How is the proper pressure determined for a high-pressure tire?

Job No. 36

PATCHING INNER TUBES

References.—Part Two, p. 495.

Operations Necessary to Perform the Job.

1. Inflate tubes and locate puncture or cause of leak.
2. If valve is defective, clean or replace same with a new valve.
3. If tube is punctured, clean rubber surface, prepare patch, and vulcanize same on tube or use "cold-patch" method.
4. Test tube for leaks.

Names of Materials, Tools, and Operations to be Reviewed before Performing the Job.

Materials.—Patching rubber, cement, sandpaper.
Tools.—Water tank, vulcanizer, pressure gauge, knife.
Operations.—Patching, vulcanizing, inflating tubes.

Description of Operations.

When repairing an inner tube, apply a pump and inflate the tube as much as it will stand. Then remove the pump and inspect the tube for a leak by placing the tube under water. If the valve leaks, readjust or replace the valve inside with a new core. If a leak located around the valve stem is found, the pressure nut should be tightened. If a puncture is found, mark the spot with an indelible pencil, deflate the tube and thoroughly dry the surface, to repair the puncture. Freshen the surface around the hole with sandpaper or a file, apply a thin coat of cement, and allow it to dry. Now press on a patch which has been prepared in a similar manner, or vulcanize the patch, depending upon whether the cold patch is to be used or whether a vulcanized patch is wanted.

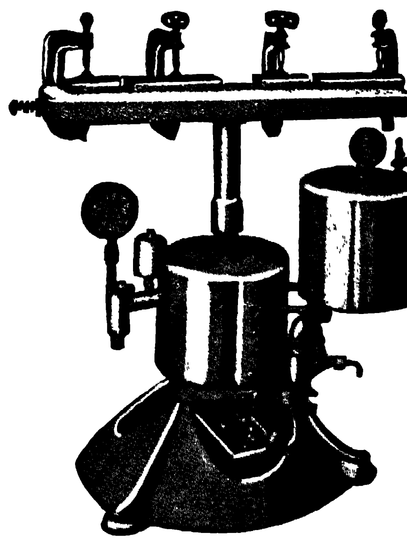


FIG. 36a.—Tube Repairing Plant.

The most important factor in applying a successful patch is to have the tube thoroughly cleaned with gasoline and roughened with sandpaper before the patch is put on. Considerable pressure should also be placed on the patch after it is applied, until the cement has time to set. A little powdered talc should be rubbed on the patch when dry, so that it will not stick to the casing. It is more convenient, however, and more satisfactory in the long run, to have a spare tube in the car so that the punctured tube can be taken to a repair shop and repaired by vulcanizing. A well-vulcanized patch over a puncture makes the tube as good as new.

The purpose of demountable rims is to avoid the necessity of changing tubes on the road, and an extra tire should be carried already inflated on the spare rim at the rear. It is needless to say that whenever the tires on the car are inflated the spare tire on the rear should also have air so that it will be ready for use when needed.

Under no circumstances should a tire be run deflated. The tube and casing will both be ruined if run for any distance. In case of a blow-out when a spare tire is not available, a temporary repair may be made by inserting a blow-out patch inside the casing before the new tube is put in.

The most satisfactory type of blow-out patch is the one with flaps which extend out around the beads of the tire under the rim flanges. This is the only kind of patch that will protect the tube if the casing is weak next to the rim. Do not under any circumstances run on the bare rim or on the wheel with the rim removed. The rim or felloe band may be so badly damaged that replacement will be necessary.

Care of Inner Tubes.—A carefully folded, securely wrapped inner tube is always ready for immediate use. A loose, twisted, badly scarred inner tube, minus a valve cap and with the valve full of dirt, will cause unnecessary trouble and delay.

To fold an inner tube, remove the small plunger or valve inside by unscrewing it with the valve cap. To exclude the air, suspend the tube

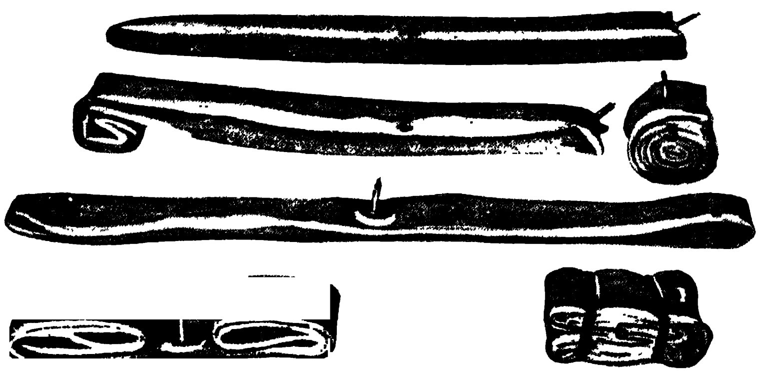


FIG. 36*b*.—How to Fold an Inner Tube.

by the valve and roll it up, beginning at a point opposite the valve. Before unrolling, replace the valve plunger to prevent the refilling of the tube with air. The following operations, illustrated in Fig. 36*b*, show how to fold an inner tube.

1. Remove the inside portion of the valve.
2. Roll tightly to expel the air.
3. Replace inside portion of the valve to prevent the air from returning.
4. Unfold, and lay flat.
5. Fold in ends.
6. Fasten in package with rubber bands.

In the case of a leaky tube do not unroll, but tie it up in this shape until repairs have been made. This plan provides a means for distinguishing between good and bad tubes.

Use talc powder and wrap all inner tubes securely before storing away in the car, to prevent damage from chafing.

Suggestions.

1. Always keep tires properly inflated.
2. Be sure to repair little tread cuts regularly.
3. Prevent blow-outs by avoiding severe jolts and by maintaining full air pressure.

Questions.

1. How can a leak in an inner tube be located?
2. How can a leaky valve core be repaired?
3. What different methods are used in patching a puncture?
4. What is the purpose of the leather washer under the nut on a valve stem?
5. When a casing is to be mounted, should the tube be flat? Why?
6. When a new tube is to be put into a casing which has "gone flat," what precautions should be taken?
7. What should be done if there is a slight fabric break?
8. What is the purpose of powdered mica or talc? How much should be used? What is the effect of using too much?

CHAPTER II

ENGINE WORK

Job No. 1

GRINDING AND ADJUSTING VALVES

References.—Part Two, p. 396.

Operations Necessary to Perform the Job.

If engine has removable head—

1. Drain water from radiator.
2. Disconnect hose and manifolds.
3. Remove cylinder head.
4. Remove valves.
5. Clean valve head, valve seat, and stem.
6. Grind valves.
7. Reassemble all parts.

If engine does not have a removable head, on L- or T-types—

1. Remove port plugs and valves.
2. Grind same and reassemble.

If engine does not have removable head, on overhead type—

1. Remove rocker arms and valve cages.
2. Grind valves.
3. Reassemble all parts.
4. Place lifters at their lowest point.
5. Adjust valve clearance, according to manufacturer's specifications.

Names of Materials, Tools, Parts, and Operations Necessary to Perform the Job.

Materials.—Valve-grinding compound, rags.

Tools.—Screw driver, valve grinder, wrenches, pliers, valve lifters, valve-grinding spring, thickness gauge, kerosene.

Parts.—Cylinder: L-head cylinder (valves on one side of cylinder), T-head cylinder (valves on opposite sides of cylinder), I-head cylinder

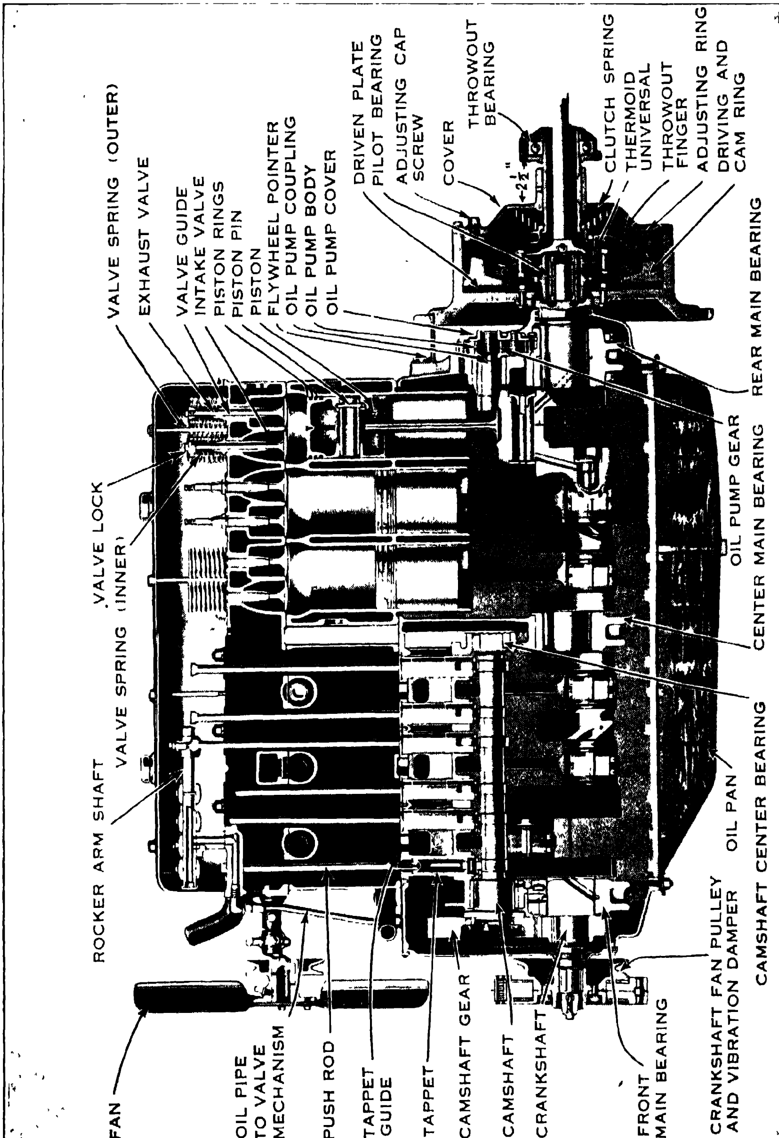


Fig. 1*a*.—Sectional View of Engine and Clutch. (Marmon.)

(valves in cylinder head), F-head cylinder (one valve in head, other on side), (cylinders of V-type engines should be numbered 1R, 1L, 2R, etc.),

inlet-valve cap, exhaust-valve cap, valve-cap gasket, cylinder-head, cylinder-head gasket, cylinder-head plug, water hose, drain-cock valve-cover, valve-cover gasket, valve-cover stud, valve-stem guide, priming-cup, poppet valve, inlet valve, exhaust valve, valve-spring, spring retainer, spring-retainer lock.

Operations.—Grinding valves, seating valves, adjusting valves.

Description of Operations.

A too-rich mixture or a poor quality of lubricating oil will sometimes cause a collection of carbon on the valve seats so that the valves will leak when they are closed. (See Fig. 1*b*.) This condition will result in poor compression in the cylinder. To test the compression on any cylinder, loosen the spark plug wires and place them so that the terminals are about $\frac{1}{16}$ inch from the cylinder head. The engine may then be turned over with the hand crank and a spark will be seen between the terminal and the cylinder at the exact time when the piston is in the firing position. The compression stroke on this cylinder occurs just before the firing point. If the compression is good the starting crank can be rocked up and down and the piston will cushion against the charge of gas in the cylinder. If the valve leaks, the piston will not cushion against the charge of gas in the cylinder. Another method of testing is by the use of a compressometer as shown in Job 10, page 282.

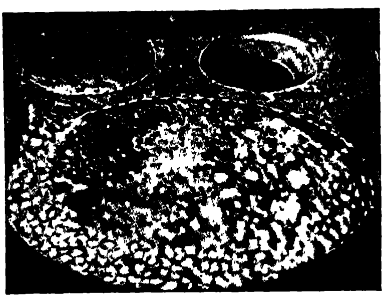


FIG. 1*b*.—Cylinder and Piston Coated with Carbon.

Poor compression is sometimes caused by the sticking of the piston rings. The trouble is more often due to leaky valves. Unless the compression is very good in the other three cylinders, it is best to "grind in" all of the valves while the work is being done. The exhaust valves are usually the first to leak.

Before proceeding to grind the valves, make certain that they are not being held open by insufficient clearance between the valve stem and the contact head of the valve tappet. These contacts should be adjusted so that a 0.003 to 0.008 thickness gauge can be inserted between the contact head and the stem.

The time that valves will run without grinding varies with so many conditions that it is practically impossible to make a definite rule

as to how often they should be ground. If the valves leak it is necessary to grind them regardless of the length of time they have been used.

If the engine has a removable head, drain the radiator, disconnect the hose and manifolds, and remove the engine head. The next operation is to remove the valves and see that they are marked so that they will be replaced in the same set. When removing the valves use valve lifter (Figs. 1*f* and 1*g*) to compress the valve springs so that the key in the end of the stem can be removed. The valves can then be lifted out and all the carbon cleaned from the head, the stem, and the valve seat.

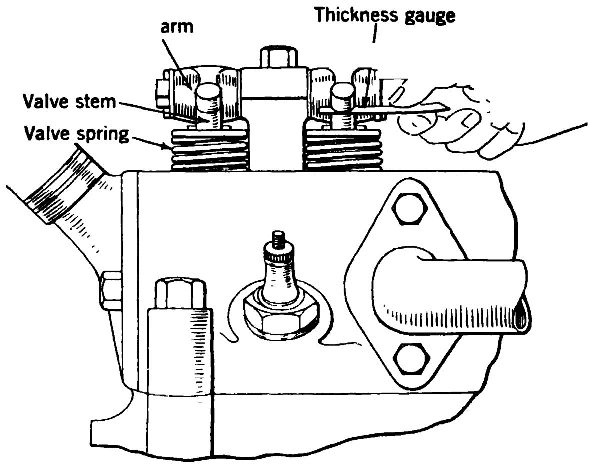


FIG. 1*c*.—Measuring Valve-stem Clearance.


FIG. 1*d*.—Valve Coated with Carbon.

To grind valves it is necessary to use a valve-grinding compound. This compound is spread sparingly on the face of the valve where it comes in contact with the seat, and the valve is replaced in the seat and turned about a quarter of a turn first one way and then the other. (Fig. 1*h*.) A light spring should be placed on the stem below the head. The spring should have sufficient tension to lift the valve so that its position may be changed at frequent intervals. As it is turned to the right, push it against the


FIG. 1*e*.—Valve after Refacing.

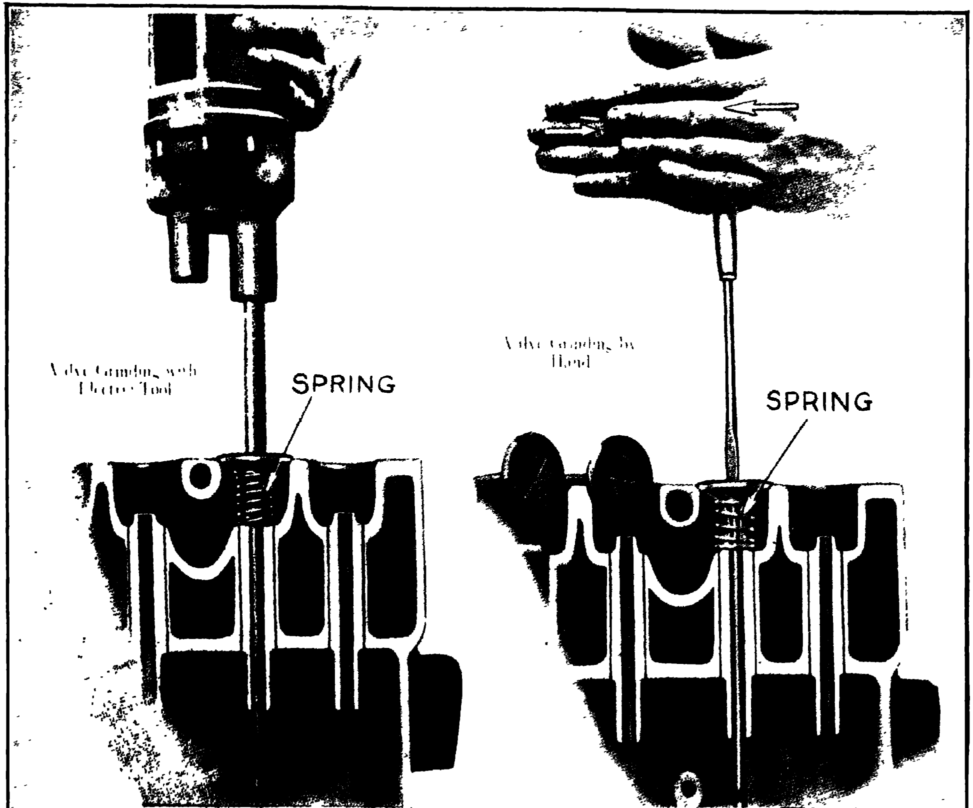


FIG. 1h.—Grinding Valves.

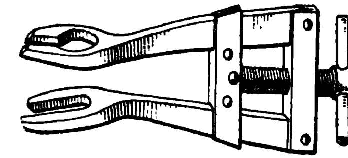


FIG. 1f.—Valve Lifter.

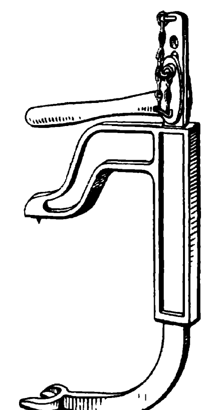


FIG. 1g.—Valve Spring Li

seat with a gentle pressure and then allow the spring to raise the valve and push it again into the seat as it is turned in the other direction.

When there is a good clean surface all the way around the valve head and the valve seat, the compound should be removed and the valve tested by making a number of soft lead-pencil marks, about $\frac{1}{4}$ inch apart, around the edge of the valve seat. Place the valve in its seat and rotate as in grinding. If a portion of each pencil mark has been erased it is evident that the valve is seating properly. If some of the marks have not been erased in part, the valve should be ground until it has a uniform seat around its entire circumference. Another way it may

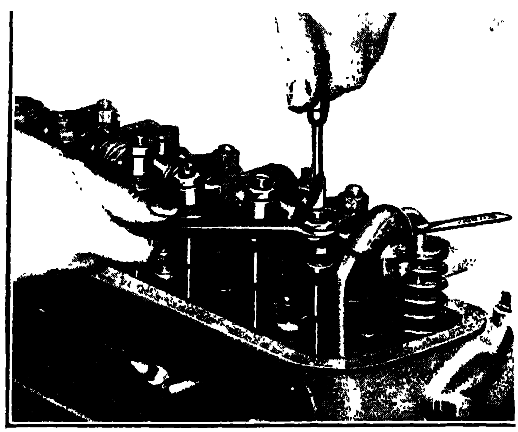


Fig. 1*i*.—Adjusting Valves. (Marmon.)

be tested is by putting a light coat of bearing blue on the cylinder contact. Insert the valve in the cylinder and turn back and forth about $\frac{1}{8}$ of a turn, remove valve, and see if the valve face shows a perfect ring of blue. Proceed in the same manner until all the other valves have been ground and tested, and then reassemble all parts of the engine and test its compression.

If the engine does not have a removable head and it is an L- or T-type, it is only necessary to remove the port plugs and grind the valves as previously described. If the engine has "valves in head" (Fig. 1*i*) and the head is removable it must be removed so that the valves may be ground in the head block. Where the valves are seated in cages, it is only necessary to remove the cage and grind the valves in the cage.

After the valves have been ground, place the piston on compression dead center (so that the lifters will be at the lowest point) and adjust the gap between the valve stem and the lifter to manufacturer's specifica-

tions. (See Figs. 1*i* and 1*j*.) After tightening the lock nuts, grind and adjust the valves in the remaining cylinders in the same manner.

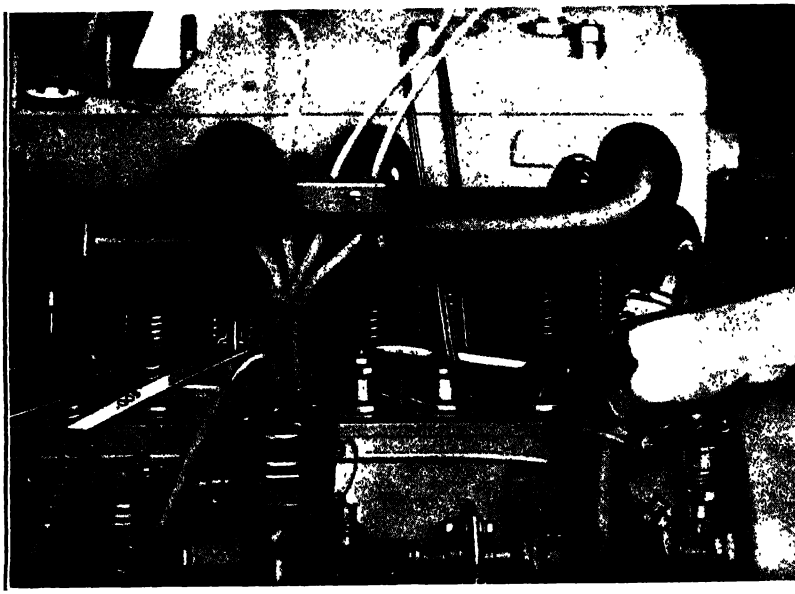


FIG. 1*j*.—Adjusting Valve or Valve Lifter.

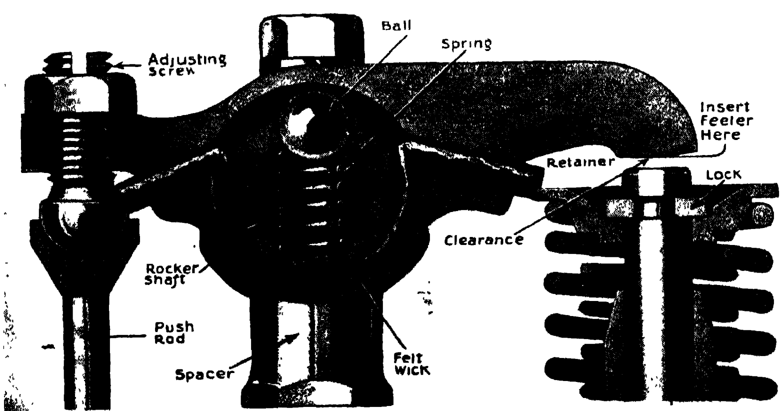


FIG. 1*k*.—Details of Overhead Valve Mechanism.

The amount of grinding depends upon the condition of the valve seat. When the valve seems to have been ground sufficiently, remove

it and clean both the valve and the valve seat with kerosene, and test by either of the two methods described.

Questions.

1. How may you determine when the valves need grinding?
2. How would you remove a valve?
3. How would you grind a valve?
4. How would you determine when a ground valve seats properly?
5. How would you adjust the valve clearance?
6. Explain how to test the compression of an engine.
7. How much clearance should be allowed between an inlet-valve stem and the push rod? Why?
8. How much for an exhaust valve?
9. If the adjustment is too close, what kind of a sound will be produced?
10. If the valves become interchanged after being ground, will they seat properly?
11. What materials are used in grinding valves?
12. What special tools are on the market to do this work?
13. What precaution should be taken with the valve stems and guides after grinding the valves?
14. What is the effect of a loose fit in an inlet-valve stem? In an exhaust-valve stem?

Job No. 2

RESEATING AND REFACING VALVES

References.— Part Two, p. 396.

Operations Necessary to Perform the Job.

1. Remove valves.
2. Reseat with taper reamer.
3. Reface valve in a lathe or with special valve-facing tool.
4. Grind and test valves.
5. Reassemble all parts.
6. Adjust valve-tappet clearance.

Description of Operations.

When valves have been used for a long time and have been frequently ground, the seats become grooved until it is impossible to grind them to a good seat. It then becomes necessary to reseat and reface them before grinding.

To reseat and reface valves, remove and clean the valves as for grinding. Reseating and refacing tools are shown in Figs. 2*a* and 2*b*.

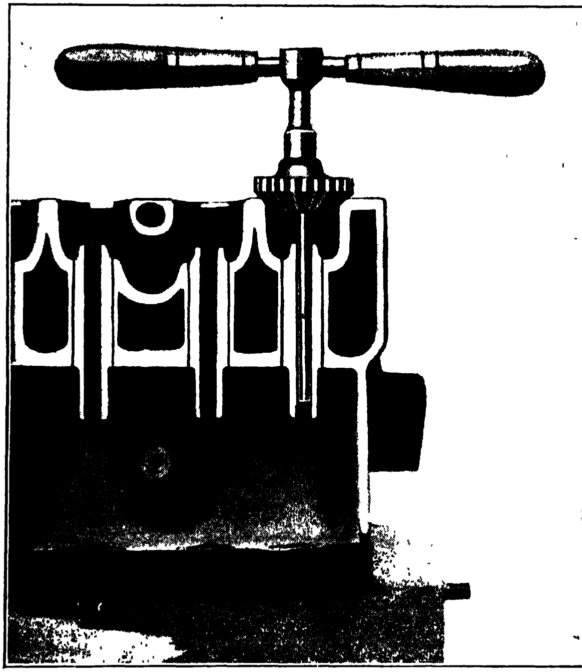


FIG. 2*a*.—Facing Valve Seats.

Reamers or reseating tools come in different sizes, and may be purchased at any tool-supply house. When the valve has been removed and cleaned, cut a hole in the center of a small piece of emery cloth and

FIG. 2*b*.—Valve-refacing Tools.

slip it over the lower stem of the reamer with the rough side down. Place the reamer in the valve seat and turn it forward so that the emery will remove the polish from the valve seat. Remove the cloth and place

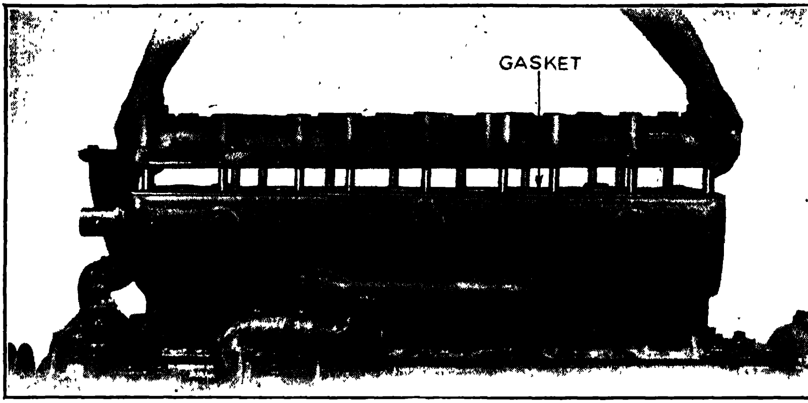


FIG. 2c.—Removing Cylinder Head.

the reamer in the seat as shown in Fig. 2a. A steady pressure placed on the reamer as it is turned will cut the seat to a clean smooth surface.

Care should be taken not to cut away more metal than is necessary to true up the seat. The more the seat is enlarged the sooner it will be necessary to use an oversize valve.

To reface the valve, place it in a refacing tool. One of these is shown in Fig. 2b. Adjust the cutting tool so that it strikes the valve face at the correct angle. The seating is accomplished by pressing the rotating valve disk against the cutting tool until a good clean face is secured (see Fig. 1e). After the valves are reseated and refaced, grind and replace them in the cylinders as described in Job No. 1. Proceed in the

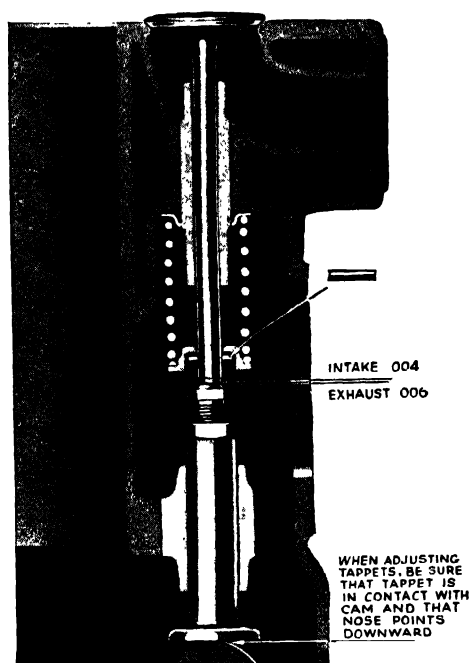


FIG. 2d.—Valve Adjustment on L-type Motor.

same manner until all of the valves in the engine are finished. The valve tappets should be adjusted in the same manner as in Job No. 1.

Questions.

1. What is the angle of a valve seat?
2. Why is it necessary to reface and reseat the valves?
3. What tools are used for this job?
4. Explain fully how you would reface a valve.
5. Explain fully how you would reseat a valve.
6. What would you do next after the valve is reseated and refaced?
7. If no special valve lifter is available how can one be improvised?
8. Which valve is the most likely to need reseating? Why?
9. What should a mechanic do to prevent mixing valves when the engine is overhauled?

Job No. 3

ALIGNING A CONNECTING ROD

References.—Part Two, page 400.

Operations Necessary to Perform the Job.

1. Remove the connecting rods.
2. Remove the pistons from the connecting rods.
3. Install rods on the fixture and line up.
4. Oil and assemble all parts.

Materials and Tools Necessary to Perform the Job.

Aligning fixture, bending bar, feelers, combination square.

Description of Operations.

When the pistons and connecting rods have been removed from an engine and have been rebushed or taken apart, the rods are very often distorted or bent out of alignment, thereby causing undue wear on the cylinder walls and pistons. The rod should be placed upon the aligning fixture as shown in Fig. 3*a*, and lined up.

To align the rod, select the proper size bushing for the lower end of the connecting rod, place the contact plate and arbor in the upper con-

necting-rod bushing, and place the connecting rod on the aligning fixture. Test the clearance between the four-point contact plate and the aligning

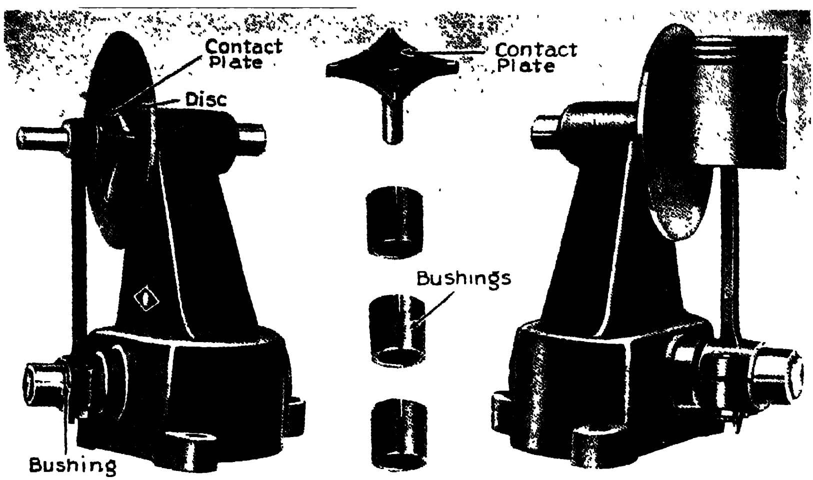


Fig. Aligning a Connecting Rod.

disk. If the connecting rod is properly aligned the clearance will be the same at all four points. If out of line, remove the rod from the fixture, place in a vise, and bend it in the proper direction with a bending bar or a monkey wrench. The rod should now be placed on the fixture and tested again; repeat these operations until the rod is properly aligned.

If the equipment does not include an aligning fixture, the rod may be aligned by the use of a straight arbor and a combination square, as shown in Fig. 3*b*.

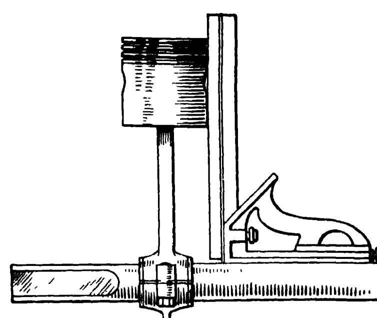


Fig. 3*b*.—Testing Alignment with Combination Square.

Questions.

1. How does a connecting rod become bent?
2. What is the effect of a bent connecting rod on a cylinder wall? On a piston?
3. What is the effect of a twisted connecting rod?
4. How can the repairman determine whether a connecting rod is bent?

Job No. 4

REPLACING VALVE-LIFTER GUIDES

References.— Part Two, p. 396.

Operations Necessary to Perform the Job.

1. Remove cover plate or other parts as necessary.
2. Remove worn valve-lifter guides.
3. Replace with new guides.
4. Adjust valves.
5. Reassemble all parts.

Names of Parts to be Reviewed before Performing the Job.

Parts.— Valve-lifter, lifter guide, guide clamp, lifter roller, lifter-roller pin, valve-adjusting screw and lock nut, valve-rocker, valve, push-rod, mushroom lifter.

Description of Operations.

After an engine has been used for a length of time the valve-lifters and guides become worn and noisy. In this case it is best to install new valve-lifter guides. These guides may be purchased from the dealer handling the particular car to be repaired. The first operation is to remove the old lifter assembly (Figs. 4*a* and 2*d*) and examine the new lifter and guides to see that the lifter works freely in the new guide. Next place the new part in the position from which the old part was removed and readjust the valves. At the present time many engines are built with cluster lifters as shown in Fig. 4*b*. The entire cluster may be removed and a new set easily installed.

Questions.

1. What are the effects of worn valve-lifter guides?
2. Explain fully how you would install new valve-lifter guides.
3. Is it necessary to remove the camshaft in order to remove the guides?

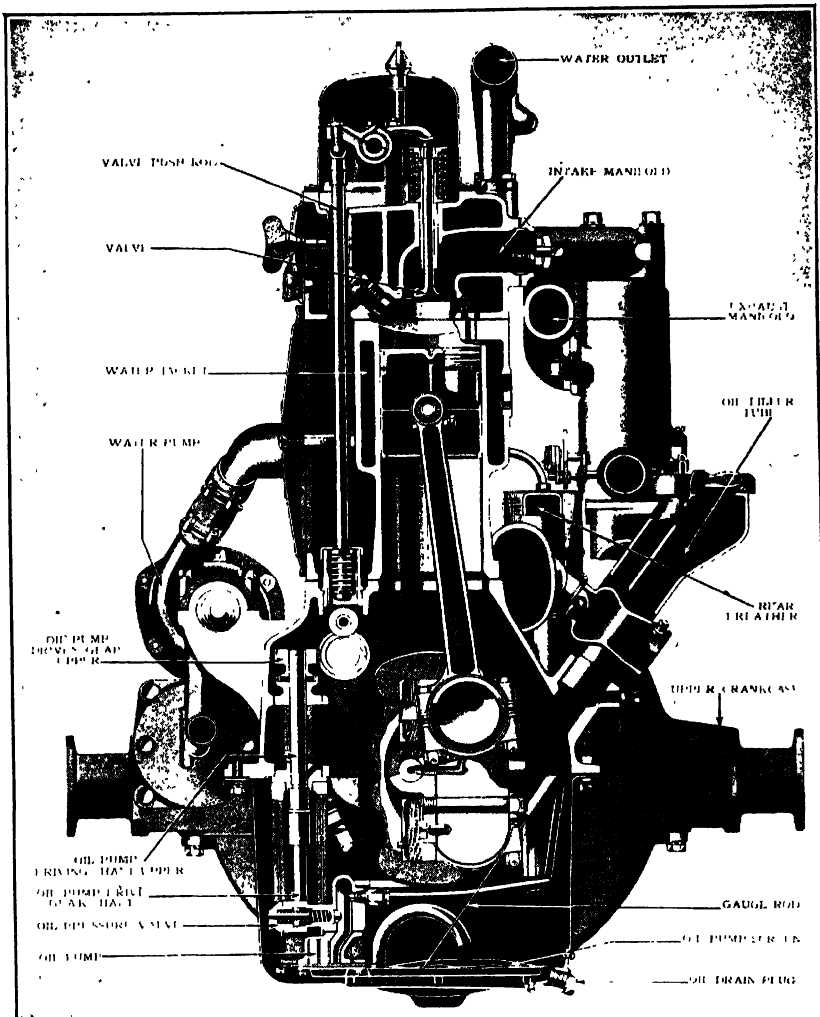


FIG. 4a.—Valve Mechanism on Overhead Engine. (Buick.)

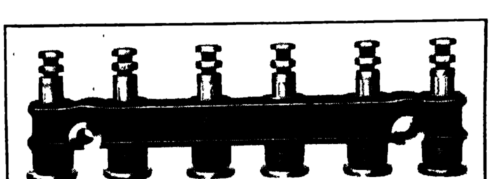


FIG. 4b.—Cluster Lifters.

Job No. 5

ADJUSTING MAIN BEARINGS

(Without Removing Motor)

Operations Necessary to Perform the Job.

1. Remove crank case.
2. Remove spark plugs to relieve compression.
3. Test bearing for wear.
4. Remove nuts and cap from bearing to be adjusted.
5. Take out shims necessary to take up play.
6. Replace cap, tighten nuts, and test bearings.
7. If adjustment is not satisfactory, repeat above operations until it is satisfactory.
8. Release bearing nuts one-half turn.
9. Adjust each remaining bearing separately.
10. Tighten all bearing nuts.
11. Test crank shaft for fit.
12. Replace locking device.
13. Assemble and replace all parts.

Names of Parts to be Reviewed before Performing the Job.

Oil-pan gasket, bearing, crank-shaft front-bearing, oil pan, oil pump, oil gage, drain plug (upper half and lower half), front-bearing cap, rear-bearing shims, center-bearings.

Safety First.—If a pit is used, avoid the danger from a spark igniting the gas or oil. Block the car securely before getting under it to work. Disconnect starting-motor cable. Use clean rags.

Description of Operations.

The life of an engine depends largely upon its bearings. One bearing gone wrong will soon cause the wreck of the entire engine. Knowing this fact, some drivers continue to run an engine with a loose bearing until it finally burns or hammers out, or the connecting rod is broken and crashes through the side of the crank case to remind them forcibly that repairs are necessary. If such negligence is countenanced, costly repairs are inevitable.

An engine knock is always a herald of trouble, and among those conditions which might cause its development are loose crank-shaft and

connecting-rod bearings. Only experience can make one proficient in locating and distinguishing these knocks from each other. The noise produced by a loose bearing is especially difficult to identify and locate, inasmuch as the sound varies according to differences in conditions. Usually a main crank-shaft bearing knock takes the form of a dull pounding or thump, while a knock in a connecting-rod or piston-pin bearing is sharper and higher in pitch.

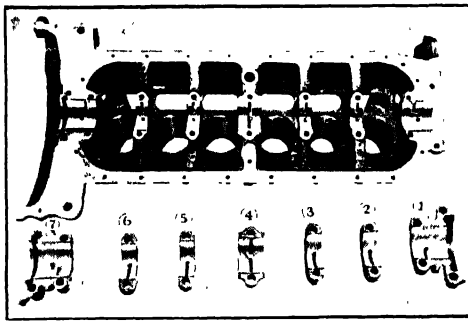


FIG. 5a.—Crank Case, Showing Main Bearings.

When the main bearings become worn, causing a knock, it is necessary to adjust them. In order to make this adjustment, drain the oil and remove the oil pan. All the main bearings, including caps, should be plainly marked so as to show their relation to each other and to the crank case. Remove the cap of the first bearing and take out one or two shims on each side to make up for the wear. These shims are cut from sheet brass as shown in Fig. 5b.

After the shims are removed, replace the cap, tighten the nuts as much as possible, and line up cotter holes. Turn the shaft to feel the fit of the bearing. If the shaft turns hard, the bearing is too tight. Replace a thin shim on each side. If the shaft turns free with just a slight tension, it is a good fit, except on pressure-feed bearings where there should be approximately 0.0015 inch clearance between the bearing and the journal. Never back a bearing nut to the cotter-key hole as this will loosen the bearing. When all the nuts are in line with the cotter-key holes test the crank-shaft again to be sure the bearing fit is still satisfactory. When satisfied the bearing is correctly fitted, *release the nuts* in order to free the bearing so it will have no effect on the turning of the shaft while adjusting other bearings.

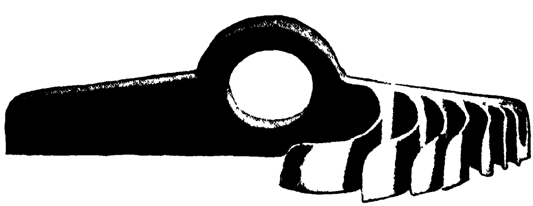


FIG. 5b.—Laminated Shim Stock.

Proceed in the same manner to adjust the remaining bearings. *When all the bearings are properly adjusted, tighten all nuts,* insert cotter

keys, and test the shaft to see that it is not too tight. When all the main bearings are correctly adjusted, it should be possible to turn the engine with the crank. After making certain the bearings are correctly adjusted, reassemble all parts. When a bearing has become worn beyond the possible limits of adjustment, and in cases where it has been scored through lack of sufficient lubrication or has become damaged otherwise, it will be necessary to make a replacement of the complete bearing, as in Job 8, page 118. While the foregoing operations appear simple to the inexperienced man, they are extremely dffiicult to perform satisfactorily except after considerable practice.

Questions.

1. How do you know when the main bearings should be adjusted?
2. How would you prepare the engine to adjust the main bearings?
3. Explain how you would adjust the main bearings.
4. How would you know when the main bearings are properly adjusted?
5. What particular care should be taken in adjusting pressure-feed bearings?
6. From what material are the crank-shaft bearings made?
7. Are they removable?
8. What provisions are usually made for adjustment?
9. How are main bearings lubricated in most cars?
10. If every bearing is set to bind a small amount, will the engine be difficult or easy to crank when completely assembled?
11. Should the engine be cranked by hand or with a starter after the bearings have been adjusted? Why?

Job No. 6

ADJUSTING CONNECTING-ROD BEARINGS

References.—Part Two, pp. 400.

Operations Necessary to Perform the Job.

1. Block up front of car.
2. Drain oil.
3. Remove crank case, disconnecting oil lines. if necessary.
4. Inspect bearings.
5. Remove bearing cap.
6. Remove one or two thin shims.
7. Replace cap and tighten nuts.
8. Test bearing.
9. Repeat until correct adjustment is made.

Names of Parts to be Reviewed before Performing the Job.

Connecting rod, straight, forked, blade (V-type engine), cap, bearing (upper half and lower half), cap stud (or bolt), cap nut, bearing shims, dipper.

Description of Operations.

Looseness of a connecting-rod bearing is indicated by a metallic knock when the motor is running idle. The looseness may be traced to an individual bearing by short-circuiting the spark plug of the cylinder to be tested. (See Fig. 8*b*, p. 277.) If the connecting-rod bearing has caused the knock, the sound will change and, as a rule, appear as a double knock when the cylinder is prevented from firing. The bearing may also be tested by the use of a compressometer as shown in Fig. 10*a*, page 282.

FIG. 6*a*.—Peeling Off a Lamination, or "Shim."

To tighten the bearings remove the crank case and, after removing the cotter keys from the castellated bearing nuts, take off No. 1 bearing cap and adjust. All bearing caps and rods should be marked before removal, in order to insure their return on the same rod and in the same position. The two halves of the bearing are separated by metal shims (Fig. 5*b*) and the bearing may be tightened by removing a sufficient thickness of shims to bring the two halves closer together. Only one sheet should be removed at a time (Fig. 6*a*). The same number of shims of the same thickness should be removed from each side. Enough should be removed so that no looseness can be felt in the bearing. After the nuts are drawn tight the looseness can be felt more readily if the spark plugs are removed so that the compression will be relieved. Be very careful not to get the bearings so tight that the motor is not perfectly free when turned with the hand crank.

If there are no liners the side of the caps must be filed down and then the cap replaced and the nuts drawn tight. Now turn the crank shaft or tap the end of the caps lightly with a hammer to test the tightness of the fit as shown in Fig. 6*e*. After the bearing has been fitted and the cotter-key holes are in line with the castellated parts of the nuts, described in Job No. 5, *back the nuts one-half turn* to free the bearing on the shaft so

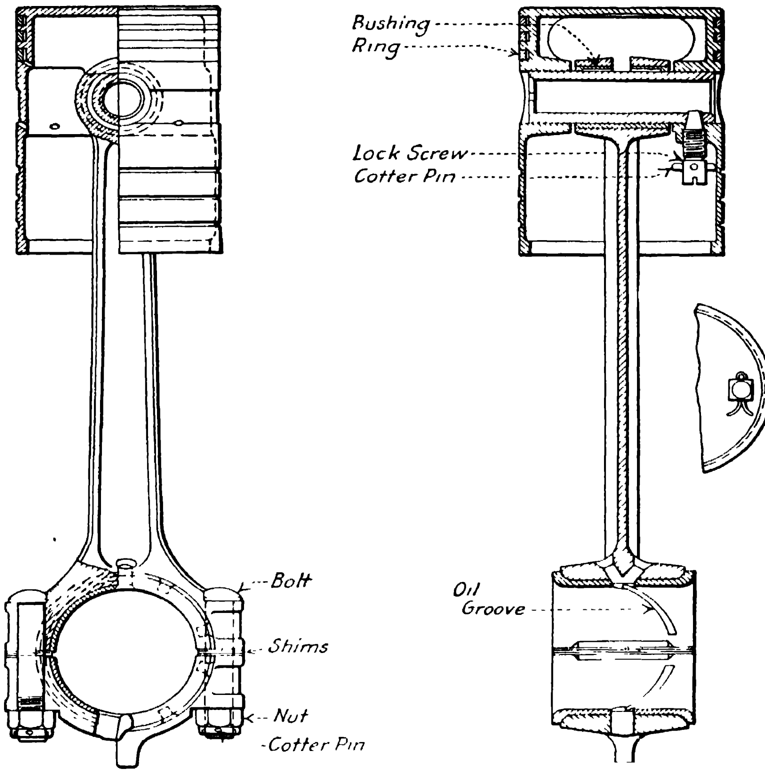


FIG. 6b.—Connecting-rod Assembly.

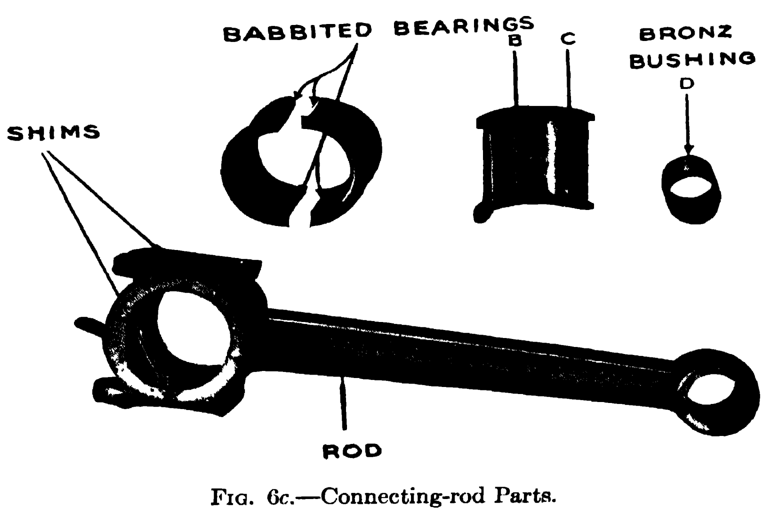


FIG. 6c.—Connecting-rod Parts.

it will not have any effect on the turning of the shaft and thus interfere with the adjustment of the next bearing. Proceed in the same manner

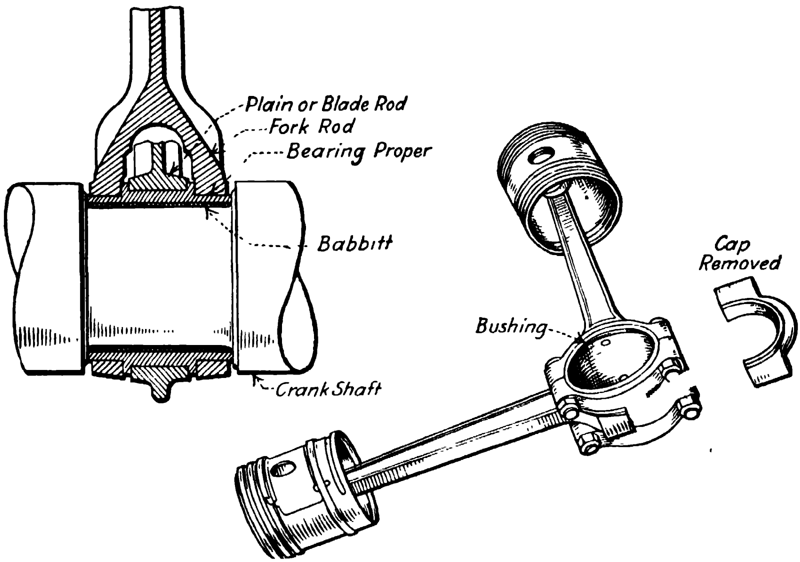


FIG. 6d.—Connecting Rods on a V-type Engine.

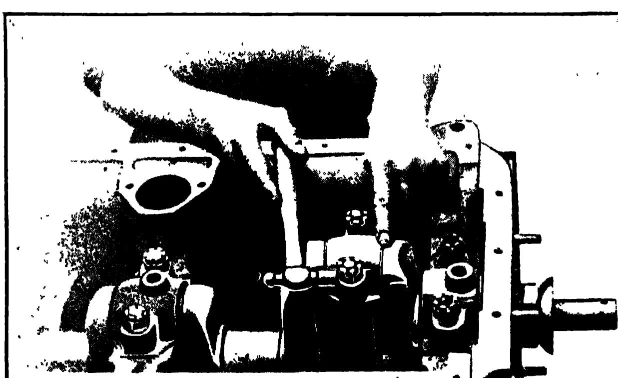


FIG. 6e.—Testing Connecting-rod Fit.

with each bearing separately until all the connecting-rod bearings are adjusted, then *tighten the nuts on all the bearings* and replace the cotter keys or set the locking devices. A cut of a connecting rod and bearing

is shown in Fig. 6*b*. Figure 6*d* shows a forked type of connecting rod that should not be filed; however, the cap of the blade rod may be filed.

After all connecting-rod bearings are properly adjusted, the nuts tightened down and the cotter keys inserted, replace the crank-case gasket and put on the crank case.

Safety Precautions.—Always disconnect starter cable before working on motor.

Questions.

1. How would you prepare the engine before adjusting the connecting-rod bearings?
2. Explain fully how you would adjust the connecting-rod bearings.
3. Explain the construction of a bearing so it may be adjusted when worn.
4. If shims are not used, how would you adjust the bearings?
5. After the bearings are adjusted, what particular precaution should be taken?
6. How are loose connecting-rod bearings located?
7. What is the difference in sound between a loose main bearing and a loose connecting-rod bearing?

Job No. 7

FITTING NEW CONNECTING-ROD BEARINGS

References.—Part Two, p. 400.

Operations Necessary to Perform the Job.

1. Remove connecting rods.
2. Remove old bearings.
3. Replace with new bearings.
4. "Blue" shaft and "spot" bearings.
5. Scrape high spots and repeat until bearings show 75 per cent blue surface.
6. Adjust bearing to crank shaft.
7. Reassemble all parts.

Names of Material, Tools, and Operations to be Reviewed before Performing the Job.

Material.—Bearing blue, shim stock, bearings, cotter pins.

Tools.—Bearing scrapers, file, wrenches, hammer.

Operations.—" Blueing " shaft or journal, " spotting " bearings, " scraping " bearings.

Description of Operations.

When connecting-rod bearings are worn or broken, as they will be found to be in many cases, it is necessary to put in new parts. The bearings universally used are cast in a die, and are usually a bronze back with a babbitt lining. When a new bearing is installed it is necessary to fit it to the shaft on which it is to run.

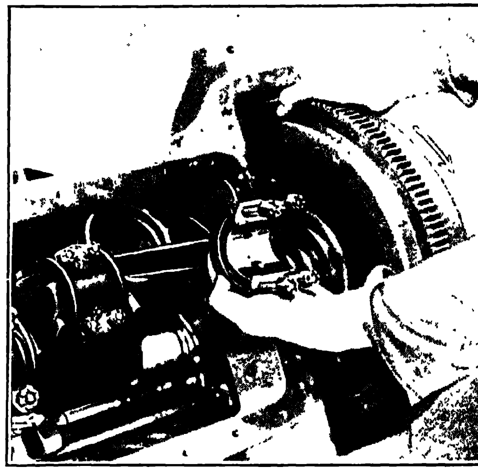


FIG. 7*a*.—Removing Connecting-rod

The first job is to remove the crank case, disconnect the connecting rod, and pull it out, as shown in Fig. 7*a*. When the connecting rod has been removed take the old bearings out of the caps and install the new bearings. The bearing is usually held in the caps by means of screws. After the new bearing is installed, if it should project above the cap, cut it down with a file. When it is flush with the edge of the cap, the next operation is to fit it to the journal on the shaft. Coat the journal with a light coating of bearing blue to aid in locating the high spots. When

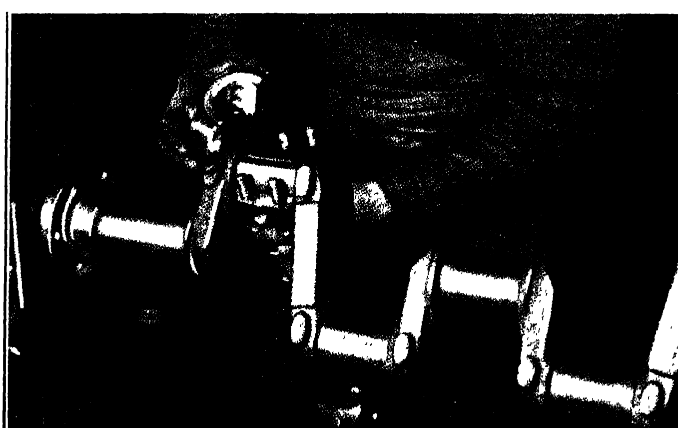


FIG. 7*b*.—Testing Connecting-rod Bearing.

fitting the bearing to the journal, place half of it on the journal and turn the bearing back and forth.

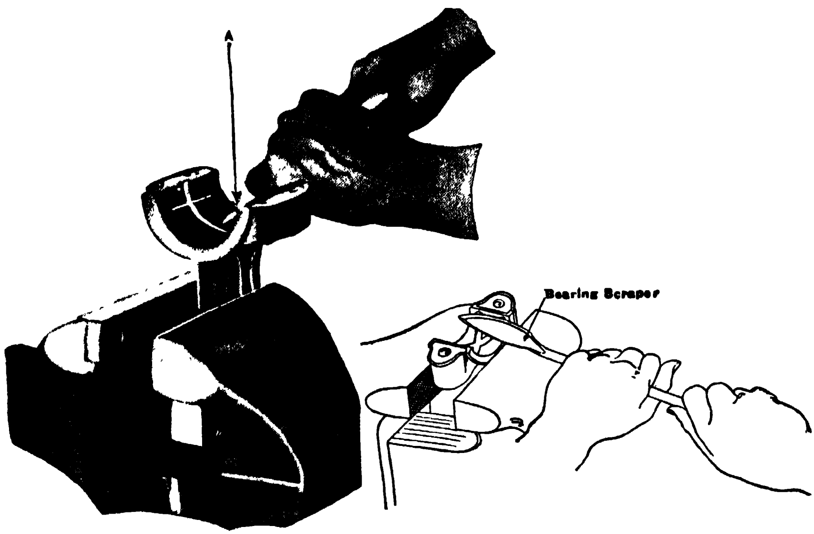


FIG. 7c.—Scraping a Connecting-rod Bushing.

Remove the cap or rod and note that all the high spots of the bearing which touched the journal have been colored blue. The next job is to scrape the bearing. Place the connecting rod in a vise, as shown in

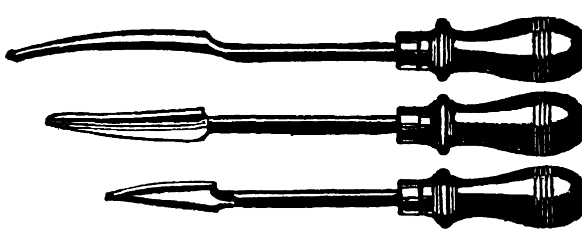


FIG. 7d.—Bearing Scrapers.

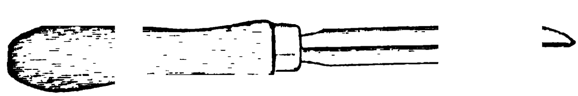


FIG. 7e.—Three-edged Bearing Scraper.

Fig. 7c, and scrape bearing where blue marks are visible. Clean the bearing with a rag, place it on the journal, and "spot" it again.

Continue these operations until 75 per cent of the bearing is marked blue after being removed from the journal. It may then be regarded as a good fit.

The bushing in the lower half of the bearing should be spotted and treated in the same manner. The next operation is to bolt the connecting rod to the shaft, rock back and forth, then remove and inspect for high spots as in Fig. 7*b*. If more than one new bushing is installed, the repairman should follow the same instructions in fitting all of them. After the bearings are fitted and adjusted, reassemble all parts and test the operation of the engine.

Questions.

1. How would you prepare to install a new bearing?
2. Explain fully how you would fit a new connecting-rod bearing.
3. What care should be taken in "spotting" a new bearing? Is it necessary?
4. From what material are the bearings in the larger end of the connecting rod made?
5. Are the bearings removable or are they permanently fixed to the end of the rod?
6. Are the bearings of solid white metal or is the backing of other metal?
7. What is the advantage of this construction?
8. What provision is made for adjustment of the bearing?
9. From what material are the shims usually made?
10. What would be the objection to using paper shims?
11. If no shims are provided, how can the bearing be taken up?
12. How should the cap be protected from the jaws of the vise while it is being filed?
13. What will be the effect of rocking the file instead of filing parallel?
14. Will a scraper need to be sharpened any oftener when scraping an old bearing, than when scraping a new one? Why?
15. If an old bearing, which has been taken up by removing shims, binds, will it be more or less liable to give trouble than a newly fitted bearing which binds the same amount? Why?
16. If each bearing in an engine binds a little, will it be easy or difficult to turn the engine when it has been completely assembled?
17. If the bearings that bind are all freshly scraped, will they remain tight for some time or will they soon become free?
18. If one bearing should bind more than the others, what might happen to it when the engine is running?
19. After the bearings have been fitted up, will it be better to make the engine pull a full load or to allow it to run idle for an hour or two?
20. Will any ill effect result if the connecting rod is turned around on the crank-pin?

21. Where are marks generally placed to indicate which way the cap should be turned when it is placed on the rod end?
22. What might be the result if the connecting rod is sprung?
23. When a bearing binds slightly, what effect will striking the rod or cap a few blows with a hammer have upon the fit?
24. Would it be better to use an ordinary hammer or one made of copper or lead?
25. When a nut on a connecting rod has been drawn up and will not turn as far as the next hole, is it better to back it off a short distance or to file the face of the nut a small amount?

Job No. 8

FITTING NEW MAIN BEARINGS

References.— Part Two, p. 363-6.

Operations Necessary to Perform the Job.

1. Remove engine from car.
2. Remove crank case and gear cover
3. Note position of manufacturer's markings on timing gears; if no marks are found, mark gears.
4. Remove crank shaft and bearings
5. Replace old bearings with new ones.
6. Coat main journals with "blue."
7. Place crank shaft in bearing and rotate.
8. Remove and scrape "high spots."
9. Repeat until all bearings show that they are in line and have 75 per cent true bearing surface.
10. Lubricate and adjust bearings.
11. Reassemble all parts and test same for adjustment and correct timing.

Description of Operations.

Crank-shaft bearings should be tested for looseness by trying each bearing separately in the same manner as for connecting-rod bearings. Never take up more than one bearing at a time, and always turn the shaft over to see that you do not get the bearing too tight. Be sure to get the bearing shells back in the same place from which they were removed. A good plan is to mark the bearing shells.

When the new main bearings are to be fitted, the engine must be removed from the frame. In order to do this, drain the radiator, drain the oil from the crank case, and remove the radiator and all the hose con-

nections. Remove all manifolds, carburetor, and ignition system, disconnect the engine base from the frame, and disconnect the universal joint.

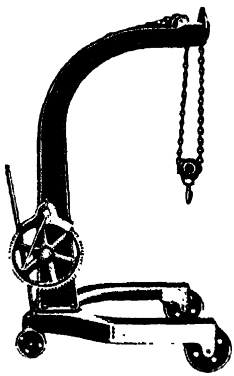


FIG. 8a.—Garage Portable Floor Crane.

FIG. 8b.—Differential Hoist.

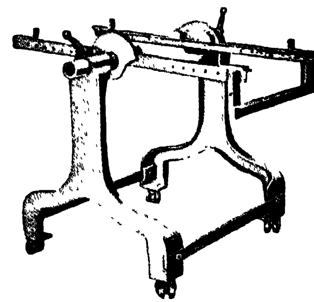


FIG. 8c.—Universal Engine Stand.

With a hoist (Figs. 8a or 8b) lift the engine from the frame and place it on an engine stand (Fig. 8c) or on a table and remove the crank case (Fig. 8d). Disconnect all connecting rods, remove the main-bearing

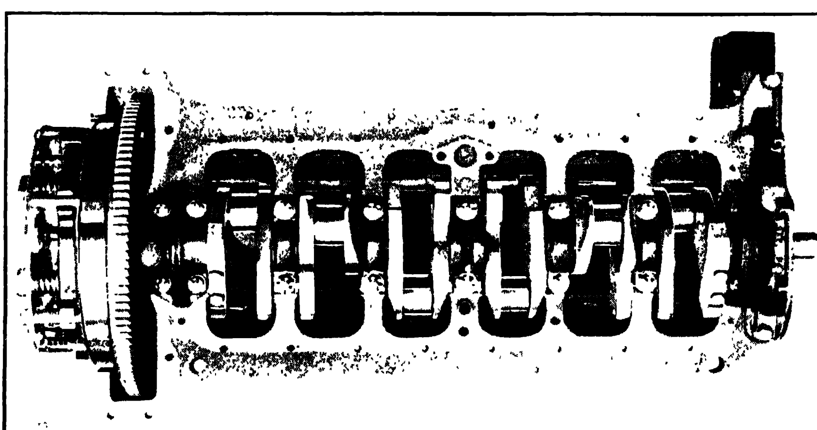


FIG. 8d.—Crank Case Removed, Showing Bearing Caps.

caps, and inspect the timing gears or sprockets for maker's marks, as shown in Fig. 12a. If there are no maker's marks, put a mark on the gears with a center punch so that when they are replaced the engine will be in " time." Next lift the crank shaft out, take the old bearings out

of the caps, and install the new ones. To fit new bearings, coat all the main journals with "blue," place the crank shaft in the case, put on the main-bearing caps, and turn the shaft as shown in Fig. 8*e*.

After revolving, remove the cap and crank shaft and scrape all the blue spots from the bushings. Repeat this until 75 per cent of the surface of all the bushings is blue. Next replace the crank shaft and adjust all the main bearings to the proper fit, as directed in Jobs Nos. 5 and 6. Replace and adjust all the connecting-rod bearings, reassemble the engine and mount it on the frame. In some cases time may be saved by lining the main bearings with a reamer. This brings all the

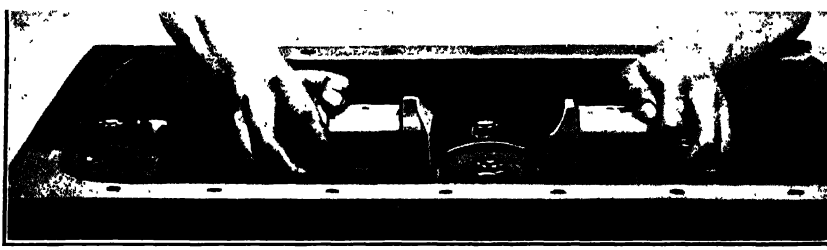


Fig. 8*e*.—Fitting Crank-shaft Main Bearings.

bearings in perfect line and does not require much scraping to make them fit the shaft. Particular attention should be given to the mesh of the timing gears when fitting the main bearings.

Questions.

1. Before installing new main bearings, what parts must be removed?
2. What attention should be given to the timing gears before removing the crank shaft?
3. How would you fit new main bearings? Explain fully.
4. What particular care should be taken when fitting all new bearings?
5. What attention should be given to the timing gears when reassembling the engine?
6. What are " high spots " on a bearing?
7. How are main bearings lubricated?

Job No. 9

FITTING NEW PISTON RINGS

References.—Part Two, p. 397-8.

Operations Necessary to Perform the Job.

1. Remove pistons.
2. Remove old rings and clean grooves.

3. Fit new rings to groove in piston.
4. Fit ring in cylinder.
5. Place ring on pistons.
6. Clean, oil, and reassemble all parts.

Names of Materials, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Materials.—Oil, emery cloth.

Tools.—File, thickness gauge, surface plate, ring knife, groove cleaner, ring compressor.

Parts.—Piston, piston pin, piston-pin lock screw, piston ring.

Operations.—Fitting rings.

Description of Operations.

When the piston rings are worn, they allow the gas to leak past the pistons and the oil to pass up into the combustion chamber; and the engine cannot be made to run satisfactorily. It then becomes necessary to put in new rings. Remove the pistons from the engine and remove all of the old rings from the piston. Clean the carbon from the head of the piston and from the ring groove. The size of the piston ring is determined by measuring the diameter of the piston skirt and the width of the groove. If the piston is 4 inches in diameter and the width of the groove is $\frac{3}{16}$ inch, the ring would be a 4-inch by $\frac{3}{16}$-inch ring.

The first operation in fitting the new ring is to try it in the groove in the piston. To determine the fit in the groove, insert the new ring and roll it entirely around the groove. It should fit snugly and not bind. If the ring is tight in the groove, it should be laid on a surface plate covered with emery cloth and rubbed down by moving back and forth, as shown in Fig. 9*a*. After being rubbed down on the surface plate, it should be tested again. If it rolls all the way around the groove without binding, it is a fit. The next step is to fit the ring in the cylinder (Fig. 9*b*).

If the ring is pushed back into the cylinder and squared up with a piston, we may test the ring for slot clearance, as in Fig. 9*b*.

In fitting new rings it must be remembered that the top ring is nearest the combustion chamber and therefore gets the hottest. More gap must be allowed for expansion on this account. The top ring, therefore, should be fitted with a clearance of not less than 0.006 inch, when tested with a feeler gauge, as shown in Fig. 9*b*. The second and third rings should have a slot clearance of not less than 0.003 inch.

A repairman cannot afford to guess at the clearance in an adjustment of this kind, for it is far too delicate to be gauged by the naked eye.

A feeler gauge must be used. Since it can be purchased at any supply store, every repairman should be supplied with this tool.

It is well to bear in mind that careful measurements insure good workmanship. Merely taking any ring that comes to hand and filing the gap so that it looks approximately right is no assurance that it will improve the compression or eliminate other troubles.

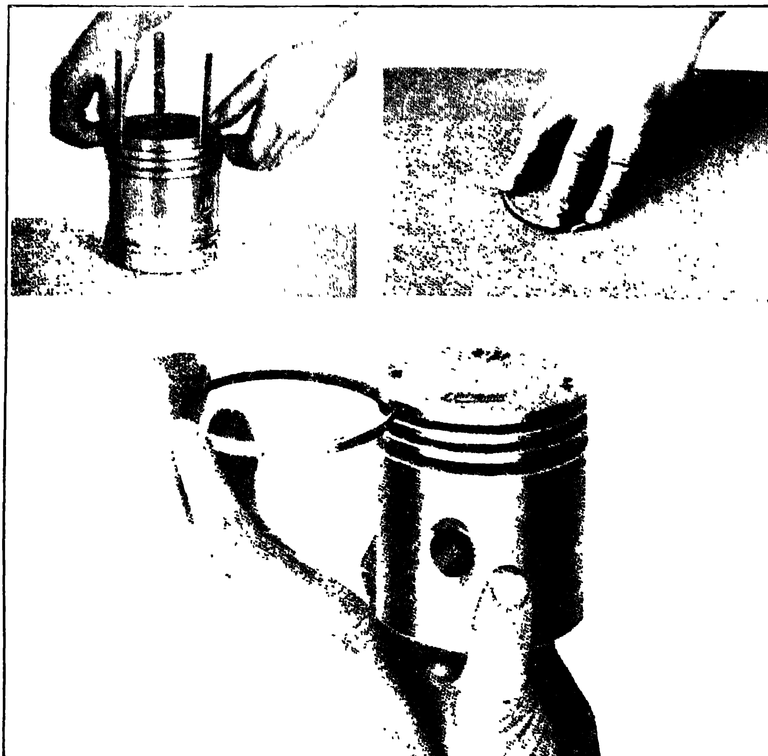


FIG. 9a—Fitting New Piston Rings

Removing rings
Rubbing down ring that is too tight in piston grooves.
Testing ring for clearance

When the rings for one piston are fitted in this manner, place them on the piston. To do this take three hack-saw blades or thin metal strips and slip them under the rings about 120 degrees apart, as shown in Fig. 9c. In this way the rings are easily slipped on the piston. Insert the piston in the cylinder and work it back and forth to be sure that no ring is binding for lack of clearance.

There should be at least 0.001 inch clearance for each inch of bore of the cylinder. If the rings do not have the proper clearance, take a small

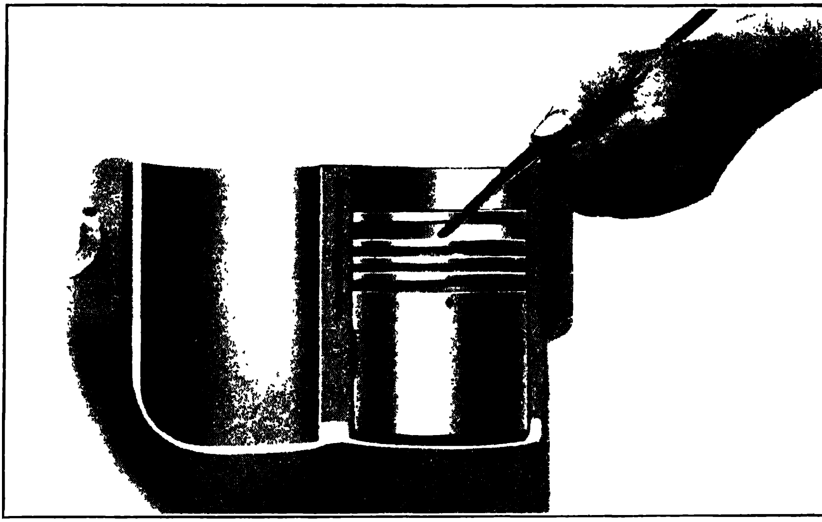


FIG. 9b—Testing Ring for Clearance.

file and file between the ends until the clearance is right, as in Fig. 9f. Then place the rings on the piston as before, and, when all the rings are fitted in the same manner, oil the piston, divide the ring slots evenly around the circumference of the piston, place the piston in the cylinders, adjust the connecting-rod bearings, and reassemble the engine.

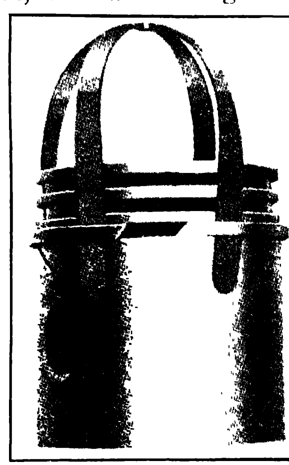


FIG. 9c.—Placing Rings on Piston

Questions.

1. How will you know when the engine needs new rings?
2. Explain in full how you would fit new piston rings.
3. From what materials are piston rings made?
4. What will be the result of stretching a ring too much in an effort to remove it from the piston?
5. How can a piston ring be removed easily from the piston?
6. In what condition are the grooves often found on an old piston?

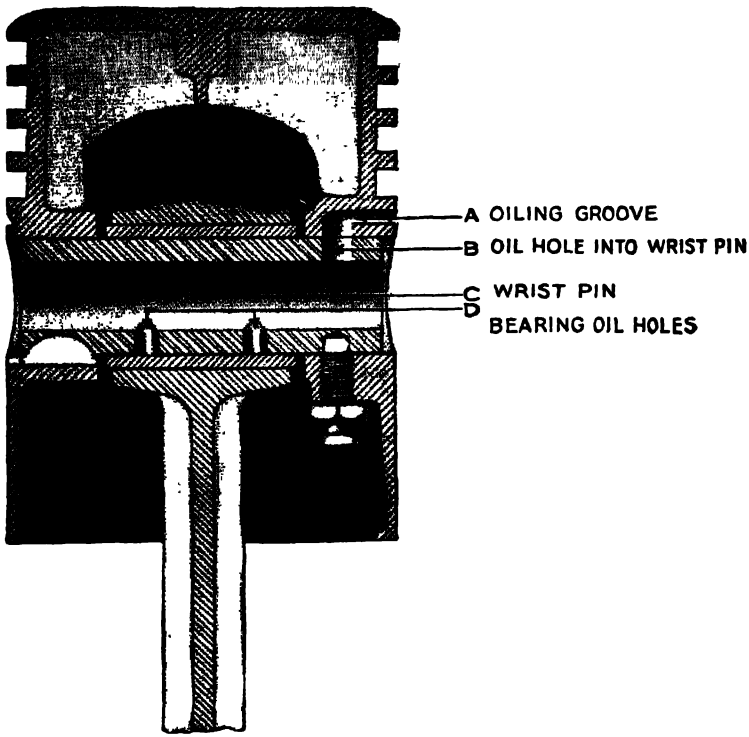


FIG. 9d.—Section of One-piece Piston.

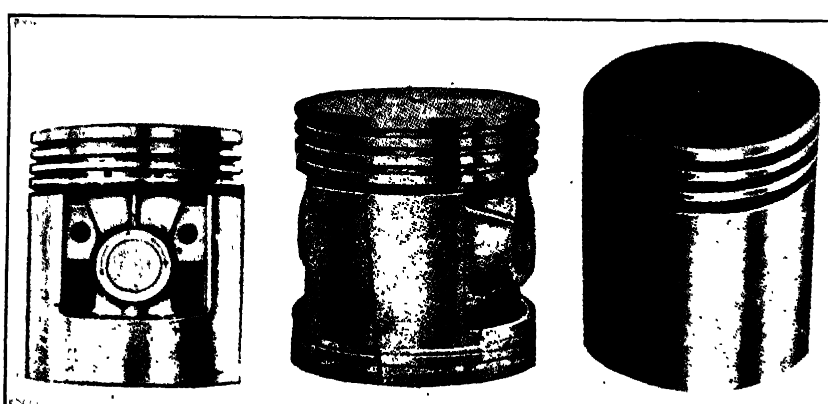


FIG. 9e.—Types of Pistons.

7. Which grooves will be worn the most? Why?
8. How does the appearance of a ring indicate whether or not it fits the cylinder properly?
9. How much clearance is desired between the ring and the parallel faces of the groove?
10. If the fit is proper, how difficult should it be to shift the ring in the groove?
11. If there is excessive clearance between the ring and the groove, what effect will this have on oil consumption?

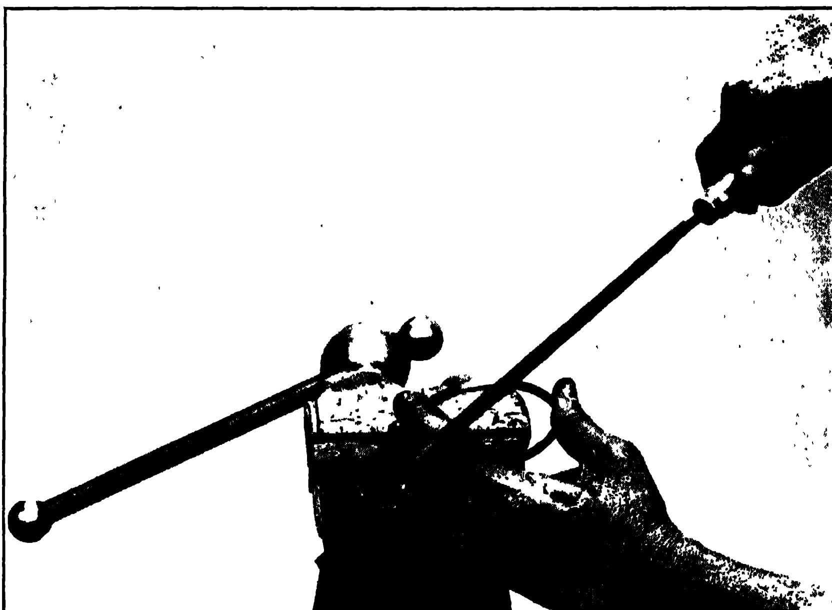


FIG. 9*f*.—Filing Piston-ring End Clearance.

12. If the ring fits the cylinder wall properly, how does the oil get past?
13. If a groove is worn, can it be straightened up with a file?
14. If a ring is too snug a fit in the groove, can it be faced properly with a file?
15. When a new ring is fitted to a cylinder, what attention should be given to the ends?
16. How much gap is needed?
17. Why is the gap needed?
18. How can it be determined whether a new ring fits the bore of the cylinder properly?

Job No. 10

GRINDING OR HONING CYLINDERS FOR NEW PISTONS[1]

Operations Necessary to Perform the Job.

1. Drain water and remove cylinder head.
2. Drop oil pan and remove pistons and rods.
3. Clean carbon from top of the cylinder.
4. Measure diameter of the cylinder bore.
5. Grind cylinder for oversize pistons.
6. Clean engine thoroughly.
7. Fit piston rings as in Job No. 9.
8. Oil and assemble all parts.

Names of Parts to be Reviewed before Performing the Job.

Cylinder, cylinder head, piston, piston rings, wrist pin, bore, combustion chamber.

Tools.—Cylinder grinder, dial indicator, feelers, portable electric motor drill, inside and outside micrometers.

Materials.—New pistons, kerosene, rags.

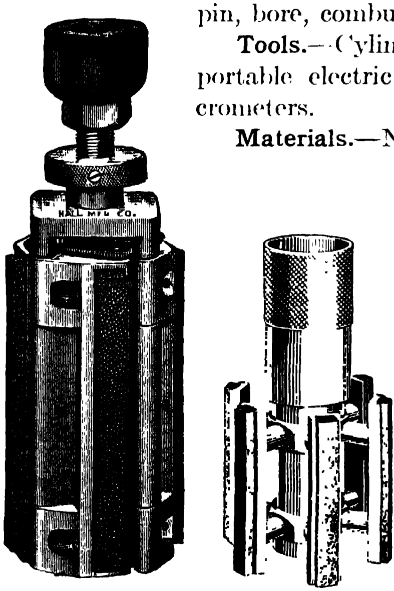


Fig. 10*a*.—Cylinder Hones or Grinders.

Description of Operations.

After long and continued use a motor reaches a point where it is necessary to resize the cylinder bores and fit new pistons. This may be done by regrinding, reboring, or honing. Different types of resizing tools are shown in Fig. 10*a*.

To grind a cylinder, remove the cylinder head, drop a pan and remove the pistons and the connecting rods. Measure the inside diameter of the cylinder bores with inside micrometers or a dial indicator, checking with the outside micrometers. Prepare the motor for grind-

[1] The trade terms "Grinding" and "Honing" are frequently used to mean the same operation.

ing by wetting rags with oil and covering the crankshaft, cam shaft, and the entire inside of the motor base, to keep grit off the parts. Select the

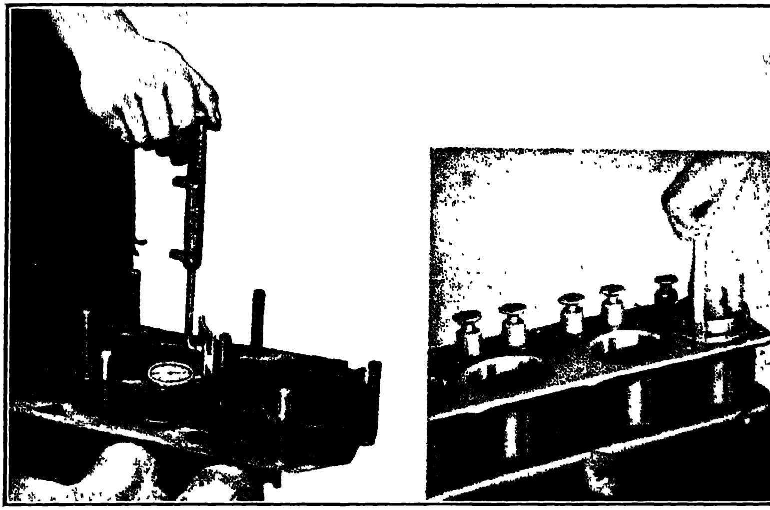


FIG. 10*b*.—Measuring Size of Cylinder.

proper size stones and install in the grinder. Insert the grinder in the cylinder bore and adjust the stones to the smallest part of the cylinder bore. Connect the electric motor to the cylinder grinder and start the motor. Keep a small stream of kerosene oil on the stones and move the grinder up and down when running. The grinder must be adjusted tight enough so that the electric motor will not spin freely. If this happens the stones will become glazed. After grinding a few moments, remove the grinder by loosening up the adjusting screw and test the cylinder bore with inside micrometers, cylinder gauge, or the piston to be used, as in Fig. 10*b*. A cast-iron piston should have 0.0007 to 0.001 inch clearance for each inch of cylinder-bore diameter; alloy pistons should be fitted

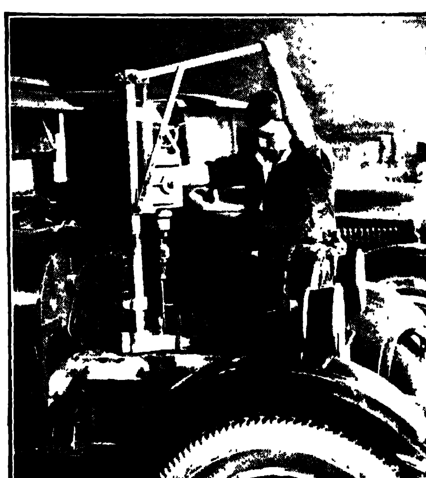


FIG. 10*c*.—Grinding. a Cylinder.

to the manufacturer's specifications. Continue grinding until the pistons fit properly.

When the pistons are properly fitted, remove the rags and clean the engine thoroughly with kerosene. Fit the piston rings as in Job 9 and oil and assemble all parts.

Safety Precautions.

1. Use care in adjusting the grinder; keep a good grip upon the motor drill.
2. Do not take the grinder from the cylinder while running.

Questions.

1. What precautions should be taken to keep grit out of the bearings?
2. How would you measure the cylinder bore?
3. What are some of the causes of cylinder wear?
4. How much clearance would you allow for a cast-iron piston? For an alloy piston?

Job No. 11

FITTING NEW WRIST PINS AND BUSHINGS

References.—Part Two, p. 403.

Operations Necessary to Perform the Job.

1. Remove pistons.
2. Remove old wrist pins and bushings.
3. Install new bushings.
4. Fit new wrist pins.
5. Reassemble all parts.

Description of Operations.

There are several methods used in assembling wrist pins and bushings. In one type the bushings are placed in the piston and the pin is fastened to the connecting rod, so that the piston swings on the pin, as shown in Fig. 11*a*. In this method a bushing is placed on each side of the piston. In another method the bushing is placed in the connecting rod and the wrist pin fastened rigidly to the piston, allowing the rod to swing on the pin, as shown in Fig. 11*b*. In the floating type the pin is not fastened in either piston or connecting rod but is held in position

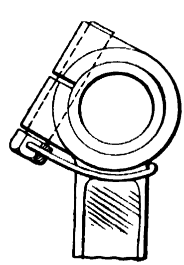


Fig. 11*a*.—Method for Holding Wrist Pin in Connecting rod.

by retaining locks which prevent the pin from damaging the cylinder wall.

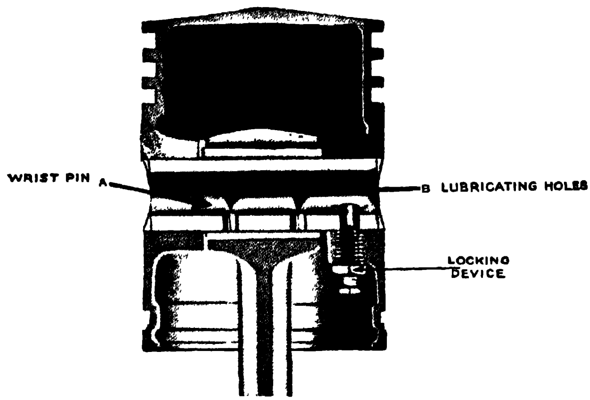


FIG. 11b.—Section of Piston and Wrist Pin, Showing Method of Assembly.

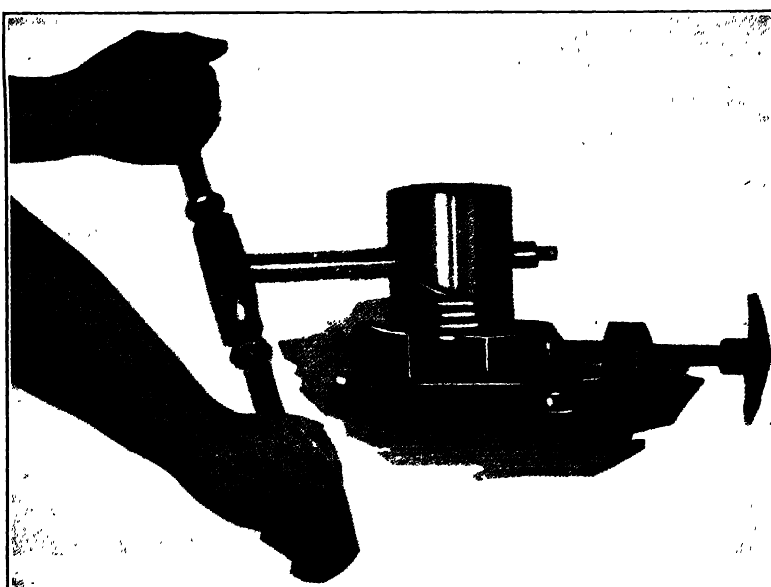


FIG. 11c.—Reaming Piston Bushings.

To fit new wrist pins or bushings mark and remove the pistons, take out the lock screw from the wrist pin and press the wrist pin out. In removing wrist pins from aluminum-alloy pistons it is a good practice to

heat the piston to a temperature of about 200° F., so that it may be handled with gloves, and then press out the pin. This will avoid damaging the piston. If the bushings are in the piston, press them out and press in the new bushings. Now test the new wrist pin to determine whether it is too large. To ream out a bushing, use an expanding reamer and run it through the bushing, as in Fig. 11c, being very careful not to make the hole too large. When the wrist pin will slip in with a snug fit and the connecting rod can be used to move the pin without binding, the fit is satisfactory. If it is too tight, it will stick when tested in this manner. Align the connecting rods as in Job No. 3. Reassemble the connecting rod and piston and set the locking device.

If the bushing is in the connecting rod, it should be reamed and made to fit the wrist pin in the same manner as described above, and the connecting rods aligned.

Questions.

1. What effect do loose wrist pins have on an engine?
2. Explain the different methods of constructing wrist pins and bushings.
3. Explain in full how you would fit a new wrist-pin bushing.
4. How would you remove the wrist pin from an alloy piston?
5. When fitting new wrist-pin bushings, why is it usually necessary to put in new wrist pins?
6. Is it necessary to give wrist-pin bushings clearance?
7. From what material is the wrist pin made?
8. From what material is the wrist-pin bushing made?
9. What kind of noise will be made by a loose wrist pin?
10. How can you locate the cylinder in which the pin is loose?

Job No. 12

REPLACING CAM-SHAFT BUSHINGS

References.—Part Two, p. 403.

Operations Necessary to Perform the Job.

1. Remove the radiator and the timing-gear cover.
2. Note "marks" on cam-shaft gear or mark and remove same.
3. Release locks or set screws.
4. Remove valves and valve springs.
5. Remove or tie up push rods.
6. Pull cam shaft.
7. Fit new bushings on shaft.
8. Replace shaft.
9. Reassemble all parts.

Names of Tools and Parts to be Reviewed before Performing the Job.

Tools.—Gear puller, reamer, tool kit.

Parts.—Cam shaft, eccentric shaft, cam-shaft timing gear, cam timing-gear key, idler gear, oil-pump gear, cam-shaft ignition-distributor gear, exhaust cam, inlet cam, oil-pump eccentric (or cam), sprockets.

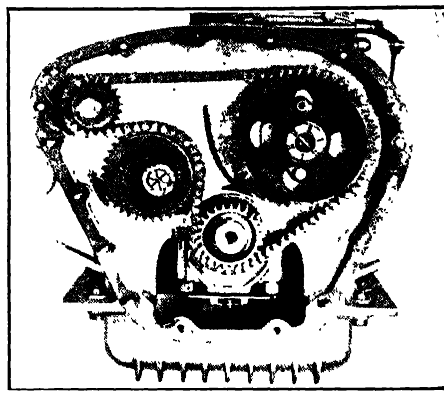


Fig. 12a.—Showing Method of Marking Sprocket Gears.

Description of Operations.

When the cam-shaft bushings are worn they sometimes produce knocks or allow end play in the cam shaft and it becomes necessary to replace the bushings. The first step is to remove the radiator and the timing-gear cover. Care must be taken to see that the timing gears or sprockets are marked; if they are not, mark them as shown in Fig. 12*a*. Next remove the cam-shaft gear, marking both gear and shaft (Fig. 12*b*), drain the oil, and remove the crank case. Release all locks on the cam shaft bushings. Remove the valves and springs, remove or tie up the push rods, and pull the cam shaft as shown in Fig. 12*c*. Try new bushings on the cam shaft. If they are too tight, ream them to a fit, oil the inside of the bushing, and replace the shaft. Test the operation of the valves as a check on the position of the timing gears or sprockets, and adjust the locking device for holding the cam shaft in place.

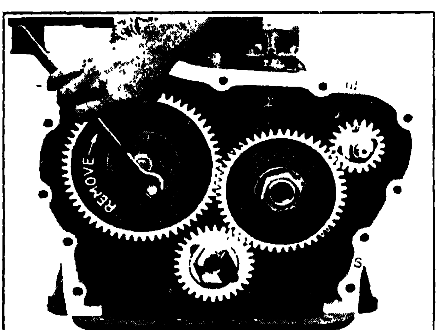


Fig. 12*b*.—Removing Timing Gears.

Questions.

1. Explain how you would disassemble the parts to remove the cam-shaft bushings.
2. What attention would you give the timing gears and sprockets before removing?
3. What care should be taken in fitting the new bushings?

4. What kinds of metals are used for the cam-shaft bushings?
5. How fast does the cam shaft of a four-cycle engine revolve in relation to the crank shaft?
6. What are the advantages of a "sleeve valve" engine?
7. When an engine is to be taken down, what precaution should be observed in order that the cam-shaft drive gears or chain and sprocket will be meshed in the same position when the engine is reassembled?
8. Is the engine timing generally marked at any other place except on the teeth of the timing gears? Where?
9. Is it necessary that there be marks to correspond to the opening and closing of all the valves in all the cylinders?
10. Are the cams keyed and pinned to the cam shaft or are they a part of the shaft?

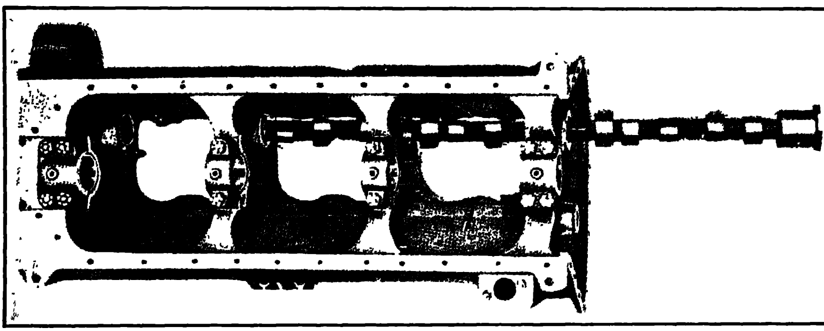


Fig. 12c.—Removing Cam Shaft.

11. If the timing of the valves is to be checked with the marks on the flywheel, what attention should be given to the tappets?
12. Will the amount of valve-tappet clearance have much effect on the time of the opening and the closing of the valves?
13. How much clearance should be allowed on the exhaust-valve tappets?
14. What is the reason for leaving this clearance?
15. Does the exhaust valve close a little before or a little after top center?

Job No. 13

INSTALLING A TIMING CHAIN

References.—Part Two, page 396.

Operations Necessary to Perform the Job.

1. Remove radiator.
2. Remove fan pulley and fan assembly.
3. Remove timing-gear cover.

4. Remove old chain.
5. Install new chain and adjust.
6. Reassemble all parts.

Names of Parts to be Reviewed Before Performing the Job.

Chain, link, hunting link, rocker, seat pin, cam shaft, crank shaft generator, sprockets, vibration damper, chain case, chain cover.

Tools and Materials.

Chisel, gear puller, scale, tool kit, silent chain, washers, gasket.

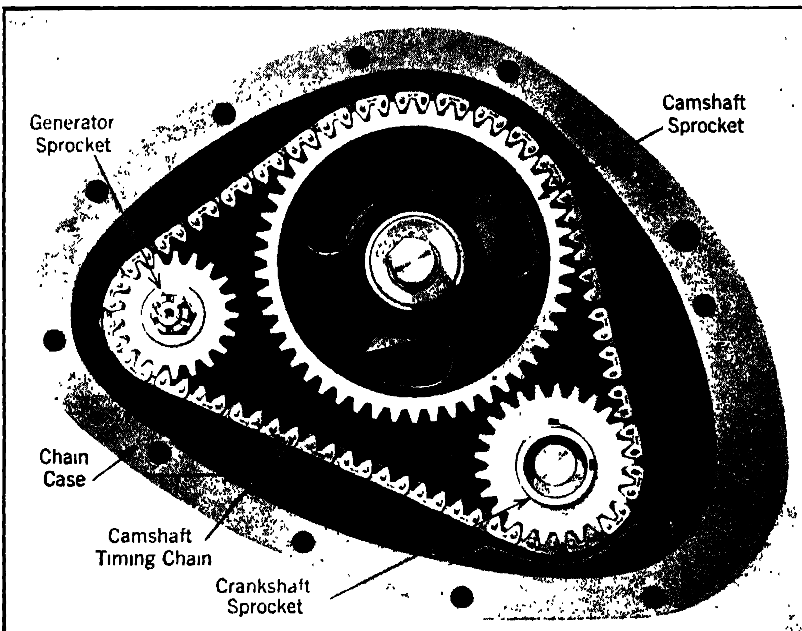


FIG. 13a.—Timing Chain and Sprockets.

Description of Operations.

Instead of using timing gears, many engines are being built with silent chains to drive the cam shaft and generator. The chain has the advantage of being quieter than gears.

After continued use it becomes necessary to adjust the chain. Some engines have an automatic chain adjuster which keeps the chain at the proper tension, as shown in Fig. 12a, page 131. Other motors provide

for chain adjustment by moving the generator away from the cam shaft. After long and continued operation the chain must be renewed.

The chain may be renewed by removing the radiator, fan assembly and timing-chain cover. Examine the chain sprockets for marks. (Most sprockets are marked to assist one in timing the engine.) Turn the engine until the sprocket marks coincide, and remove the old chain. This may be done in some cases by loosening up the chain adjustment. The chain may then be slipped off. If it is necessary to take the chain apart, look for the "hunting" link, remove the pins, and separate the chain. In some cases it may be necessary to pull off the chain sprockets to remove and install the chain.

When the new chain is to be installed, line up the sprocket marks and examine the chain for arrows denoting direction of travel. The chain must always run in the direction that the arrow points, as in Fig. 13*a*, page 133. Place the chain on the sprockets and adjust it to the proper tension. Examine the valve timing and replace the gear cover and radiator.

Safety Precautions.

Have the ignition switch off when turning the engine.

Questions.

1. Why is it necessary to adjust a chain? How often?
2. What effect does a loose chain have upon the valve timing?
3. Why is the "hunting" link used?
4. How can you tell when the chain is properly adjusted?

Job No 14

INSTALLING NEW TIMING GEARS

References.—Part Two, p. 396.

Operations Necessary to Perform the Job.

1. Remove radiator, fan pulley, and fan assembly.
2. Remove gear cover.
3. Remove old gears.
4. Install new gears.
5. Check valve timing.
6. Replace gear cover with new gasket.
7. Replace fan assembly and radiator.

Materials.—New gears, gear-cover gasket.

Tools.—Tool kit, gear pullers, feeler gauges, scale, socket wrenches.

Description of Operations.

Engines that have the valve mechanism driven by gears instead of chains are likely to become noisy because of excess wear between the gear teeth. When this condition results, a new set of gears should be installed.

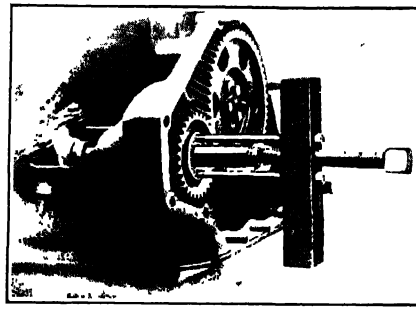


FIG. 14*a*.—Removing Timing Gears.

To install a new set of timing gears, drain the water and remove the radiator, fan assembly, fan pulley, and gear cover. Remove the old timing gears, using a gear puller as shown in Fig. 14*a*. Secure a new set of timing gears and examine the gear teeth for burrs. A small burr will cause considerable trouble. Before installing new gears examine them for manufacturer's marks showing which teeth should be in mesh. If the gears are installed according to the marks, the valve timing should be correct. However, it is advisable to check the valve timing in the following manner.

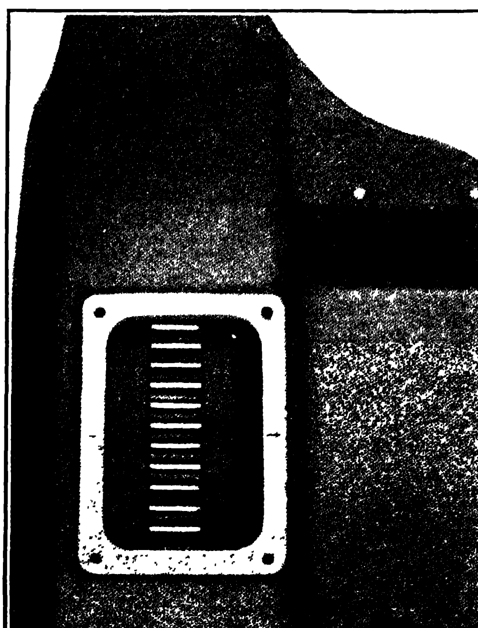


FIG. 14*b*.—Noting Flywheel Markings through Inspection Hole in Housing.

Adjust the valve lifters according to the manufacturer's specifications and examine the flywheel for marks. Usually the flywheel rim has a series of marks stamped on it, as shown in Fig. 14*b*, to indicate certain positions of the crank shaft with regard to the valve operation. The marks are usually "D.C.," for dead center or "T.D.C." for top dead center, "Ex.C." and Ex.O." for exhaust close and open, and "In.C." and "In.O." for inlet close and inlet open.

These marks mean that the valves should just open and close when lined up with the indicator mark on the flywheel housing. Turn the crank shaft until No. 1 piston is about top center, and check to see whether the exhaust valve closes and the inlet valve opens when the marks on the flywheel coincide with the mark on the flywheel housing. The time the exhaust valve opens and the inlet valve closes should also be tested by turning the crank shaft, to see whether the marks line up.

If the valves open and close past the mark, or "late," remove the cam-shaft gear, set it ahead one tooth in the direction of rotation of the cam shaft, and test again.

If the valves open and close before the flywheel and indicator marks line up, or "early," remove the cam-shaft gear and set it back one tooth against the direction of rotation of the cam shaft. When the valves are properly timed, lock the gears on the shaft, install the gear cover with a new gasket, install the fan assembly and radiator, and test the engine.

Questions.

1. When is it necessary to install new timing gears?
2. If a timing gear is not meshed properly, what will be the effect on the valve operation?
3. Why is it necessary to check the valve timing marks on the flywheel with the opening and closing of the valves?
4. Why is it necessary to consult the manufacturer's instruction manual in timing the engine?
5. What type of timing gears are used in most engines?

Job No. 15

CLEANING CARBON

References.—Part Two, p. 413.

Operations Necessary to Perform the Job.

1. Remove cylinder head.
2. Remove carbon deposits.
3. Reassemble all parts.

Description of Operations.

Carbon may deposit rapidly in the cylinders of the engine, from one of the following causes: (1) An oil of inferior quality, (2) oil not suited to the engine, (3) a surplus of oil in the reservoir, or (4) a too-rich mix-

ture. If a great deal of carbon is deposited in the cylinder, it will cause the engine to pound and lose power. The pounding is usually noticed when the engine labors or when the throttle is opened suddenly. When the accumulation of carbon becomes great enough to cause the engine to heat or to knock, it should be removed.

If the engine has been run for a length of time and a deposit of carbon is left on the piston head and valves (Fig. 1*b*, Job No. 1), it will cause

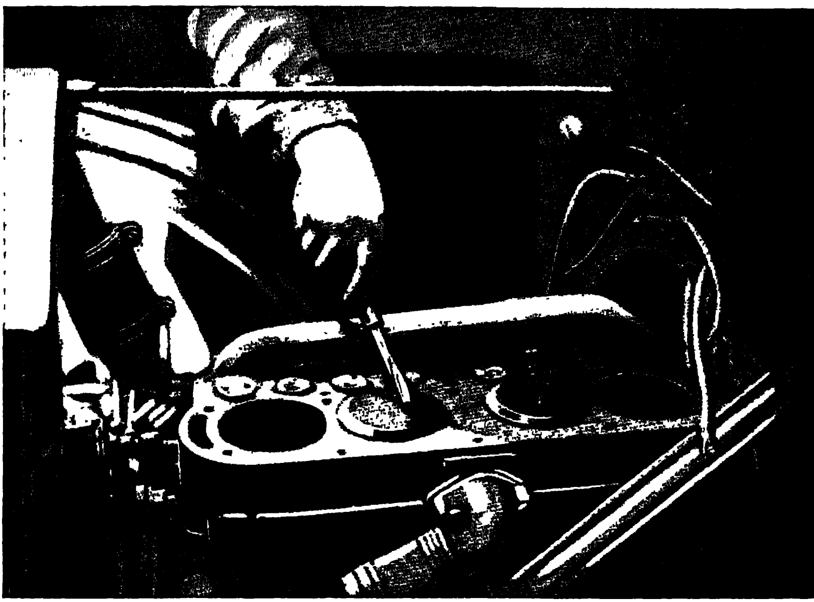


FIG. 15*a*.—Scraping Carbon.

the engine to overheat, cause pre-ignition and knocking, and also cause the valves to become leaky.

If the engine has a removable head, a good method of removing the carbon is to scrape it off. The process is identical for all makes of engines with removable heads. The first operation is to drain all the water from the radiator and engine. To do this, open the drain cock beneath the radiator.

While you are draining the radiator take off the hood and put it in a safe place where it will not be damaged. Next remove the wiring from the spark plugs and place the wires where they will not interfere with the work or be damaged. Then remove all the spark plugs and place them where they will not be broken. Remove the bolts that hold the radiator

connection to the engine or the cylinder head. Next remove the cylinder-head bolts and take off the cylinder head as shown in Fig. 15*a*. Remove the cylinder-head gasket and hang it where it will not be damaged. When possible, it is advisable to use a new cylinder-head gasket when replacing head. The hole into which the cylinder bolts are screwed should be fitted with waste or pieces of rags to keep out the carbon. With this preparation, take a carbon scraper and scrape all of the carbon from the head of the pistons and the valves and all other parts on which it has collected. Do not scrape carbon around the inlet valves when they are open. The carbon may drop into the inlet. After scraping each cylinder carefully brush off all of the loose carbon. Another way of cleaning carbon is by the use of the carbon-removing brushes and an electric motor drill as shown in Fig. 15*b*.

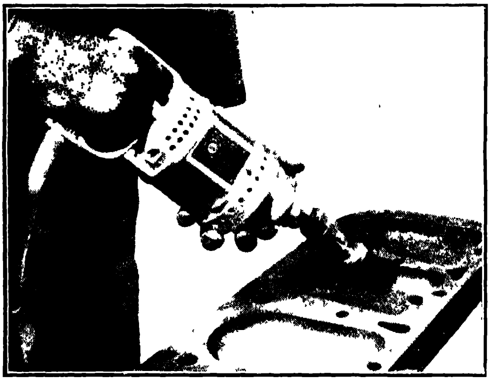


Fig. 15*b*.—Cleaning Carbon with Electrically Driven Brush.

Questions.

1. What effect does carbon deposit have on the running of the engine?
2. How does it produce this result?
3. What three conditions will tend to cause carbon to accumulate in the cylinder?
4. Will there be more or less trouble with carbon when the truck or car is operated on dusty roads than when operated on paved roads? Why?
5. What is the easiest method of getting rid of carbon in the cylinders of an engine if the head is detachable?
6. What kind of wrench is most satisfactory if the cylinder-head nuts are to be moved quickly?
7. What precaution should be taken with the gasket when it has been removed?
8. What might be the result of allowing the carbon deposit which is scraped off to get down around the rings?
9. What tools besides a scraper will be useful in removing the carbon deposit?
10. What attention may the valves need while the head is off?
11. When the head is to be replaced, is it better to leave the gasket dry or to coat it with heavy oil?

12. When a gasket has been used many times in what condition will the asbestos filling be found?
13. In what position should the pistons be in order that the gasket may remain straight while the head is set in place?
14. If cap screws are used to secure the head, what precaution should be taken with the holes? Why?

JOB No. 16

CUTTING AND FITTING GASKETS

References. – Part Two, p. 105.

Operations Necessary to Perform the Job.

1. Remove old gasket and clean parts.
2. Apply new gasket paper to face of part and mark or cut new gasket with hammer.
3. Shellac face of parts.
4. Fit gasket and reassemble parts.

Description of Operations.

Paper gaskets are used in several places on an engine, such as the crank case and the timing-gear case. For the exhaust, intake and water manifolds, prepared gasket material or ready-made copper asbestos-lined gaskets are used. If copper asbestos-lined or cork gaskets are used, they may be bought at the supply house. All other kinds of gaskets are usually cut as needed. If a paper gasket is needed, lay the paper on the face of the part on which the gasket is to be fitted, and tap lightly on the sharp edges of the part with a hammer. This will cut the paper to an exact fit for the part on which the gasket is to be placed. Where the metal part is too soft, as is the case with aluminum, place the gasket material over the part to be covered and apply a pressure with the hand around the edge. This will give sufficient marking to obtain a pattern.

Heavy, tough wrapping paper makes a good paper gasket. If the gasket is to be made of heavy prepared gasket material, a pattern should be made and the gasket cut out with a sharp knife or with a pair of snips. In fitting a paper gasket or a gasket cut from prepared material, the part on which it is to be placed should be shellacked. After the gasket has been placed on the part it should also be given a coat of cup grease and the two parts joined together. If the gasket is copper-lined it need not be shellacked but should be covered with heavy grease before the parts are fitted together.

Questions.

1. Why are gaskets used?
2. Of what different materials are gaskets made?
3. Explain in full how you would cut a paper gasket.
4. Explain in full how you would cut a gasket from gasket material.
5. If a gasket is made of paper or prepared gasket material, what should be done before it is put in place?

Job No. 17

REPLACING HEAD GASKET

References.—Part Two, p. 405.

Operations Necessary to Perform the Job.

1. Remove engine head.
2. Clean parts.
3. Cover new gasket with heavy grease.
4. Replace head.

Description of Operations.

Every engine that has a removable head uses a head gasket. These gaskets are all copper asbestos-lined gaskets and do not need to be shellacked. If the head gasket springs a leak, remove the engine head and the old gasket. Clean the cylinder block and the head thoroughly. Now coat a new gasket with heavy grease, replace the head and tighten the cylinder-head bolts in the order shown in Fig. 17*a*. Before starting

Fig. 17*a*.—Top View of Cylinder Head showing Proper Order in which to Tighten Bolts.

the engine fill the radiator. Stop the engine when it is hot and tighten the head bolts again until they are as tight as they can be made with safety.

Compression leaks may be due to the gasket having been damaged when prying off the head with a screw driver. This frequently disturbs the position of the asbestos filling and makes it impossible to pinch the gasket tight at all points. The only remedy for this defect is to replace the gasket.

The trouble may be eliminated by a few precautions in removing the cylinder head.

A special puller for removing the head may be used, as shown in Fig. 17*b*.

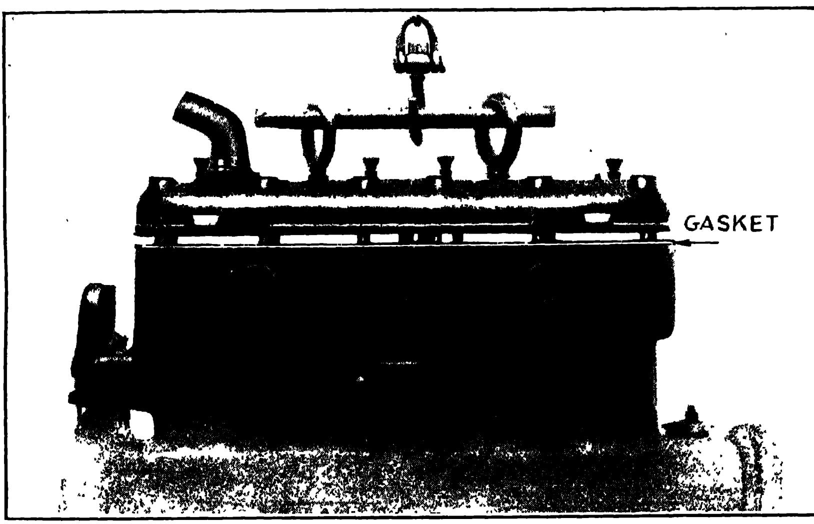


Fig. 17*b*.—Removing Cylinder Head.

For ordinary purposes the head may be loosened through compression by turning the motor over with the hand starting crank. Before doing this a stud nut at the front and rear ends should be loosened but the nut left on to prevent the possibility of lifting the head completely off the block.

If it is necessary to strike the head with a hammer in order to ease it off the studs, use only a lead or a raw-hide hammer. A steel hammer is apt to start a crack in the cast iron.

In the illustration (Fig. 17*c*) it will be noted that the stud has raised a burr around the top of the threaded portion. When this happens the gasket cannot be pinched tightly except at this one point where the clearance is reduced. The remedy for this defect is to remove the stud and counter-bore the hole as shown in Fig. 17*d*.

Leaks between Cylinders.—It sometimes happens that there is a compression leak between the cylinders at the point indicated by the arrow in Fig. 17*e*. To test for trouble of this kind cover the surfaces of the cylinder head and the cylinder block with a thin layer of white lead. Fit the gasket, tighten it down, and run the engine. If possible run the

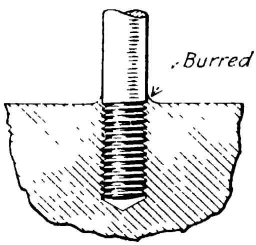


FIG. 17*c*.—Defective Stud Cylinder Head

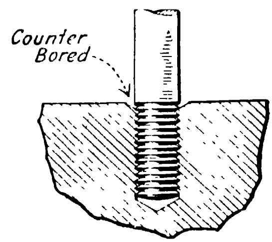


FIG. 17*d*.—Countersunk Stud Hole

engine under load so that the maximum compression and combustion pressure is obtained.

Upon removal the head will show leakage by black streaks at the points where the charge has been getting between the gasket and the machined surfaces. Trouble of this nature calls for a thorough examination of the cylinder head and the top of the cylinder block. Burred sur-

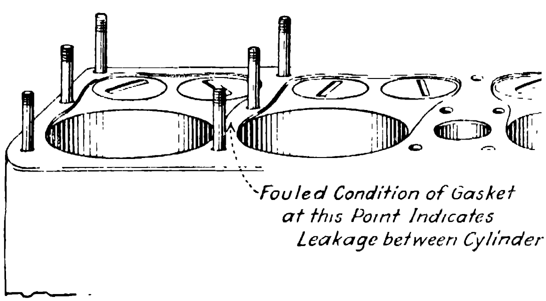


FIG. 17*e*. Head Gasket Leak.

faces will usually be found, or the gasket may have been defective. After removing the burr and cleaning the cylinder head and the top of the cylinder, place a new gasket on the cylinder and bolt on the cylinder head. Run the engine until it is thoroughly warm. While the engine is warm, tighten up the head bolts.

Questions.

1. How are head gaskets constructed?
2. What care should be taken when handling the gasket?
3. Explain how to install a new head gasket.
4. What is the objection to shellacking a head gasket?

Job No. 18

REPLACING MANIFOLD GASKETS

References.—Part Two, p. 407.

Operations Necessary to Perform the Job.

1. Remove manifold and old gasket.
2. Replace same with new gasket.
3. Reassemble all parts.

Names of Parts to be Reviewed before Performing the Job.

Parts.—Exhaust manifold, exhaust-manifold gasket, muffler, exhaust pipe, muffler outlet pipe.

Description of Operations.

If the manifold gaskets leak they must be replaced. The gaskets in the exhaust manifold are ready-made copper asbestos lined, in most cases. They can be cut from a special gasket material where the ready-made are not available. If the gaskets on the intake manifold become leaky they may be made of some type of gasket material. After the gaskets are cut and placed, be sure to tighten the manifold nuts securely or the gaskets will blow out.

Questions.

1. Explain how you would replace a gasket on an exhaust manifold. What material should you use?
2. Explain how you would place a new gasket on an intake manifold. What material may you use?
3. What material is used for gaskets on water manifolds?
4. What is the objection to using shellac on gaskets? What will oftentimes take the place of shellac?

Job No. 19

REPLACING RADIATOR HOSE

References.— Part Two, p. 489.

Operations Necessary to Perform the Job.

1. Drain the water.
2. Remove hose clamps.
3. Take off old hose.
4. Clean hose connections.
5. Cover fittings with grease.
6. Install new hose and tighten clamps.

Name of Parts to be Reviewed before Performing the Job.

Parts.— Water pump, pump impeller, pump-impeller key, pump body, pump cover, pump shaft, pump gland, pump-shaft gear, engine-water outlet, engine-water inlet, radiator hose, radiator water-fitting, pump outlet pipe, thermostat.

Description of Operations.

When a hose has been used for a length of time, it checks, cracks, and becomes leaky. The only repair is to put on a new hose.

The first operation is to loosen the hose clamps and remove the old hose. Clean the hose connections thoroughly, find the size of the new hose and the length needed, and cut the hose. Place a coating of grease in the hose and then slip on the new hose. Adjust the clamps to the right position and tighten them securely. Fill the radiator and test the connections for possible leaks.

Questions.

1. What is the greatest cause of radiator hose deteriorating or becoming leaky?
2. Explain how you would remove old radiator hose.
3. Explain how you would install new radiator hose.
4. What should you do in order to be sure the new hose does not leak when installed?
5. How would you determine the size and length of the new hose?

Job No. 20

REPAIRING OR REPLACING FAN BELT

References.—Part Two, p. 489.

Operations Necessary to Perform the Job.

1. Remove old belt.
2. Cut new belt to length.
3. Attach fastener.
4. Mount belt on pulleys.

Names of Parts to be Reviewed before Performing the Job.

Parts.—Fan, stationary fan support, adjustable fan support, fan hub, blades, pulley, fan belt, fan-driving pulley.

Description of Operations.

If the fan belt is broken or badly worn it is impractical to try to repair it except in case of emergency on the road. If the repair is made in the shop it should be done by putting on a new belt. Fan belts are made in several shapes and of several designs. Only the best material should be used when replacing a belt. After cutting the belt to the right length, attach the belt fastener and place it on the fan pulleys. Adjust the tension as the belt wears in.

Questions.

1. What would you do in case the fan belt is broken on the road and a new belt cannot be obtained?
2. What are the different types of belts?
3. How are they adjusted?
4. What different belt fasteners are used?
5. What causes fan belts to slip?

Job No. 21

INSPECTING AND REPAIRING OILING SYSTEM

References.—Part Two, pp. 408-12.

Operations Necessary to Perform the Job.

1. With engine running examine oil gauge.
2. Test for oil supply.
3. Examine oil pump to locate trouble.
4. Inspect oil lines for trouble if it is not otherwise located.
5. After locating trouble, remove parts necessary to repair same.
6. Reassemble as before.

Names of Parts to be Reviewed before Performing the Job.

Parts.—Oil-pan, oil-tank, oil-filler strainer, filler cap, oil-pump, pump body, pump plunger, plunger spring, pump inlet valve, outlet valve, pump shaft, pump gear, oil-pump following gear, pump cover, oil-strainer, strainer cap, sight feed, oil-level gauge, oil level float, oil-level glass, oil-pressure gauge.

Description of Operations.

In most automobiles the engine-oiling system is entirely automatic and requires no other attention than keeping the reservoir well supplied with the best quality of medium-grade gas-engine cylinder oil, and occasionally cleaning out any accumulation of dirt or sediment.

Nothing is more important to a motor than proper lubrication. There is no one thing which is the cause of more trouble and expense than the results of insufficient lubrication.

The motor should always be filled to the proper level (Fig. 21*a*), but a little too much oil in the motor is far better than not enough.

To inspect the oiling system first look at the oil gauge to see that there is sufficient oil in the container in the bottom of the crank case. If there is plenty of oil, start the engine and while it is running inspect to see if the oil gauge registers. If it does not, it may be necessary to remove the oil-pan and inspect the pump (Fig. 21*b*). If the stoppage is not located in this way, take a hose from an air-tank (one that is used to pump up tires will do) and blow air through all the oil lines. This should be done whenever the crank case is removed for any reason. If the oil

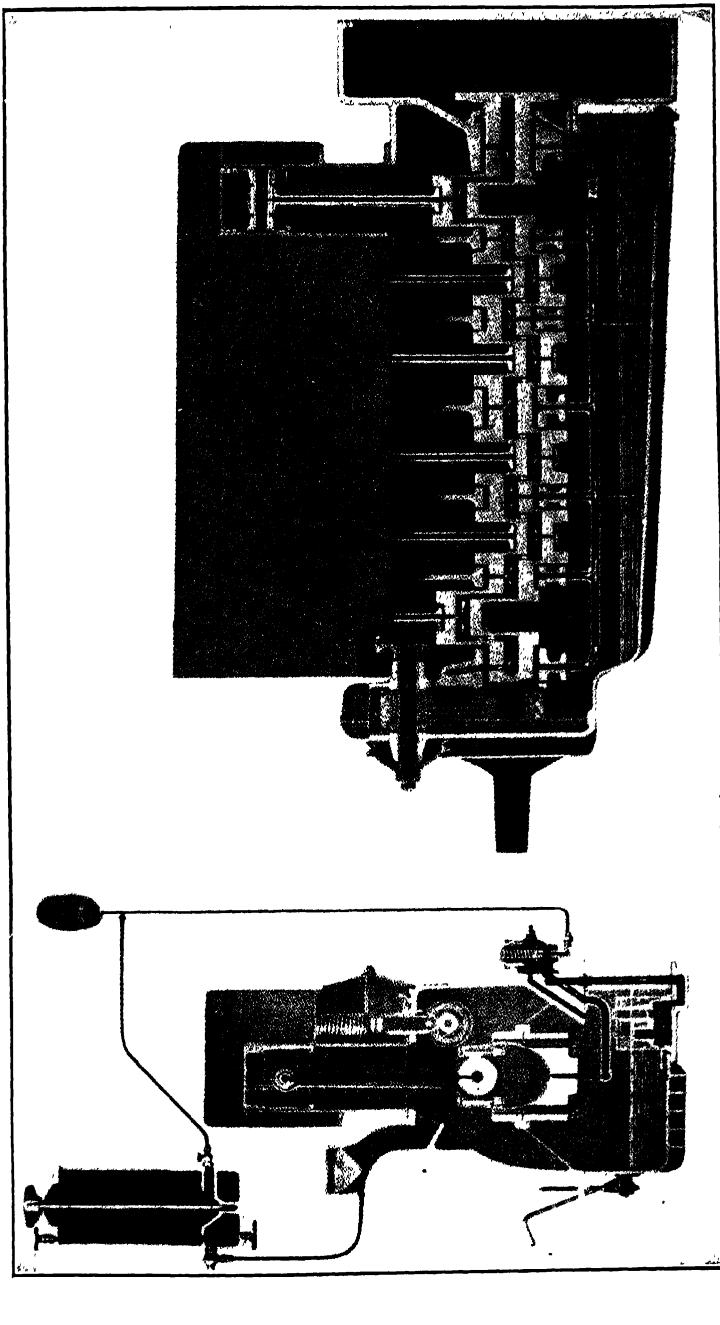


FIG. 21a.—Oil Distributing System.

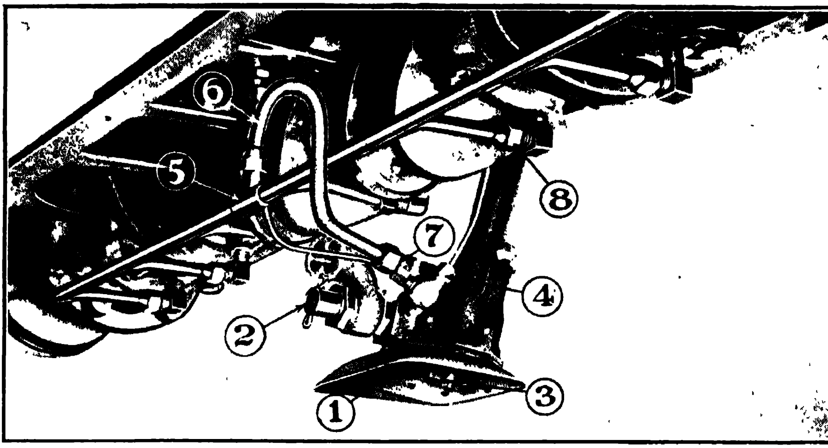


FIG. 21*b*.—Oil Pump.

1. Oil-pump screen.
2. Oil-release valve.
3. Oil-release discharge pipe.
4. Oil-tube to filter
5. Oil distribution manifold.
6. Oil pump to manifold tube.
7. Oil pressure gauge Tube Connection.
8. Main bearing connection

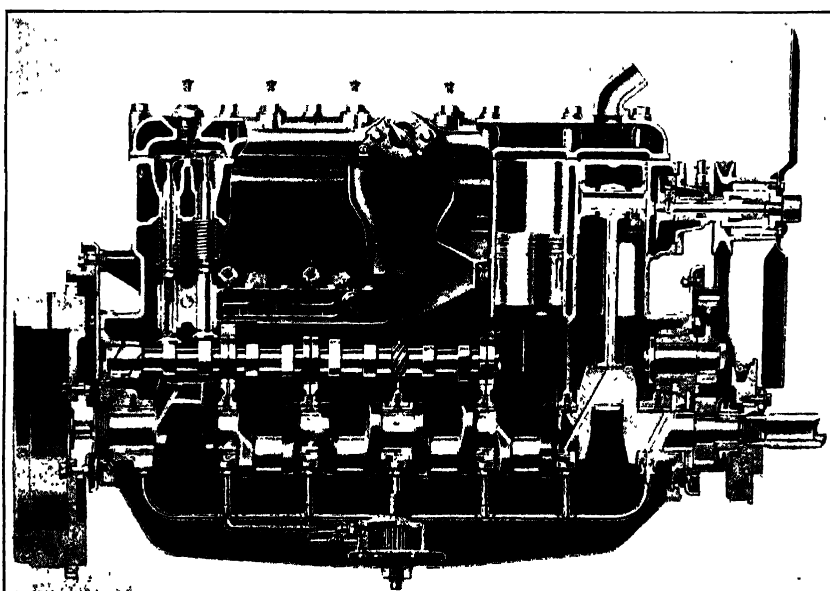


FIG. 21*c*.—Engine Oiling System.

lines are bent or broken it will be necessary to replace them with new lines or to solder the old line. Usually it is better to put in new lines.

There are several different types of oiling systems. All are similar in construction. Fig. 21*c* shows a full force-feed system in which the oil is pumped through the tubes to the main bearings and through a hole in the crank shaft to all other parts of the engine. Another system is the splash system. In this system (Fig. 88, Part Two), the oil is placed in the bottom of the crank case. The flywheel throws the oil to the top of the transmission case where some of it is caught by the tube and fed by gravity to the timing gears. The overflow, coming back to the lowest part of the pan, tends to keep a constant level in the troughs under each of the four connecting rods. The connecting rods splash the oil on the pistons and cam shaft and on all bearings.

Questions.

1. How many kinds of oiling systems are used on automobile engines?
2. What attention would you give to the oiling of an engine?
3. What kinds of oil pumps are used?
4. How would you inspect an oiling system?
5. Explain how you would " blow out " oil lines.
6. What will be the result if the metal surfaces of bearings rub against each other without the lubricating film of oil?
7. What procedure should be followed when an engine is "seized or stuck"?
8. What devices are provided to determine the amount of oil in the crank case?
9. What are the different types of engine-lubricating systems?
10. What are the different grades of oil and when should they be used?
11. In a full forced-feed oiling system what will be the effect of a loose bearing?

JOB No. 22

REPAIRING OIL LEAKS

References.—Part Two, pp. 408-12.

Operations Necessary to Perform the Job.

1. Inspect oiling system to locate leak.
2. Tighten connections.
3. Remove part in which leak is located.
4. Solder or repair leak and reassemble all parts.

Description of Operations.

If the oil-lines leak, it is first necessary to locate the leak and tighten the joints. Most oil-lines are made with solderless joints, some with the ends flared and others with the compression-type couplings as shown in Fig. 22*a*. All tubing is made of copper or brass. Before flaring the ends of tubing it is advisable to anneal the ends to avoid the possibility of splitting the tube. The tubing may be annealed by heating to a dull-red color and immersing immediately in water. If the joint is tight and the tube is defective, it is advisable to remove the old tubing and replace with a new one instead of soldering the leak. Bend the tube to shape, place the nuts on the tubing before flaring or installing compression sleeves, and install the new tube.

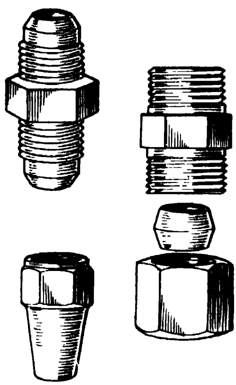


FIG. 22*a* Solderless Joints.

Oftentimes the gear cover or oil-pan may leak at the joints. When this occurs, tighten all bolts first. If this procedure does not stop the leak, remove the pan or cover, clean the joints thoroughly, install a new gasket, and assemble all parts.

Questions.

1. How would you locate a clogged or leaky oil-line?
2. How would you repair a leaky oil-line?
3. How would you repair a clogged oil-line?
4. Explain how an oil line could be "blown out" with compressed air.
5. How would you repair an oil-line that was mashed or crimped?

CHAPTER III

ELECTRICAL WORK

JOB No. 1

REPAIRING "TROUBLE" IN PRIMARY IGNITION CIRCUIT

References.- Part Two, p. 441.

Operations Necessary to Perform the Job.

1. Test battery for loose connections, corroded terminals, or discharged condition.
2. Clean terminals.
3. Recharge battery if necessary.
4. Test wires for broken circuit from battery to ignition switch to interrupter and in return to battery.
5. Use wiring diagram (if necessary) to locate primary wires; use portable test lamp to locate break in circuit.
6. Tighten loose connection, or replace old wire.
7. Tighten loose connections in switch.
8. Clean, adjust, or replace points in interrupter.
9. Test condenser for broken circuit if found to be external, restore circuit; if internal, replace condenser.
10. Test condenser for "short"; if shorted, replace condenser.
11. Inspect resistance unit on coil; if broken or "burned out," replace; if loose, tighten connection.
12. Test breaker-box insulation.

Names of Materials, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Materials.—Baking soda, distilled water, low-tension cable, wire terminals, interrupter points, soldering paste, lead wire solder, wire brush, friction tape and shellac.

Tools.—Six or 12-volt test lamp, point file, carborundum stone for truing points, breaker adjusting wrenches, thickness gauge, pliers,

screw driver, side-cutting pliers, end wrenches, soldering iron, torch, 110-volt test lamp, terminal puller.

Parts.—Switches and instruments—lighting and ignition switch, ammeter, voltmeter, volt-ammeter, charging indicator.

Operations.—Testing for "trouble," testing for "short," testing for a "ground," or "open circuit."

Care of Equipment.—Do not "short-circuit" the battery; do not use pliers in place of a wrench; protect the cushions from dirt and grease by use of covers; replace all parts; clean the car, and leave it free of all dirt due to repair work.

Description of Operations.

The primary circuit is made up of the wires and parts that carry the "battery current" through the ignition system. (The term "battery current" is understood to include all other primary currents used in ignition and produced by mechanical generators.) The primary circuit consists of the battery, spark coil, interrupter, ignition switch, and the wires connecting these parts together.

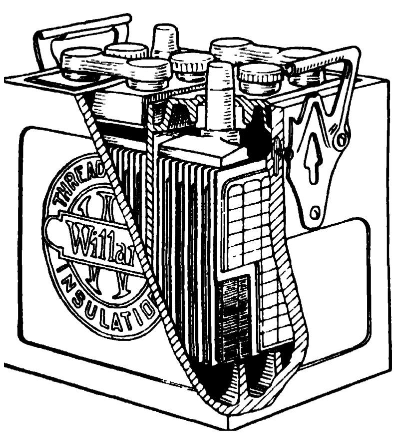


FIG. 1a.—A Cut-out Section of a Storage Battery.

Component Parts of a Storage Battery

Negative plate.	Hard-rubber cover.
Positive plate	Sealing compound.
Insulation.	Top connector
Connecting strap	Vent plug
Container with handles	Negative post.
Hard-rubber jar	Positive post
	Rubber gasket seal

If there is a break in the primary circuit, such as a loose connection or broken wires, or if the battery is in a discharged condition or has loose or corroded terminals, it will be impossible to get a current through the primary circuit.

As the battery furnishes the current for the primary circuit it should be tested for loose connections, corroded terminals, or a discharged condition. In Fig. 1*a* there are two strips of lead connecting the terminals of one cell to the terminals of the other cells. There are also two posts, to which the battery wires that carry the current to the primary circuit as well as other circuits are connected. These posts very often become coated with a corrosion which prevents the battery current from flowing from the battery post to the wire.

To remove the corrosion (see Job No. 9) take ordinary baking soda mixed with water to the consistency of cream and apply it freely to the battery posts and also to the wire terminals connecting to the posts, after separating the wires from the posts. After leaving the soda on for about fifteen minutes, clean the battery terminals and wires and, by using a wire brush, thoroughly polish each terminal. A thin coating of vaseline on the battery post will prevent it from corroding for some time. The wires should then be fastened to the battery terminals, care being taken not to let the pliers or a wrench fall across the cell connectors, as either would "short-circuit" the battery.

To test the battery, remove the vent plugs from the top of the battery, insert the rubber nozzle of a hydrometer (Fig. 1*b*) through the opening, press on the bulb, and then release the hand. This causes the solution in the battery to be drawn into the hydrometer. If the glass tube floating in the solution rises so that the number 1280 or 1300 is on a level with the solution, the battery is in a good condition. If the reading on the hydrometer is found to be lower than 1150, the battery should be recharged as described in Job. No. 10.

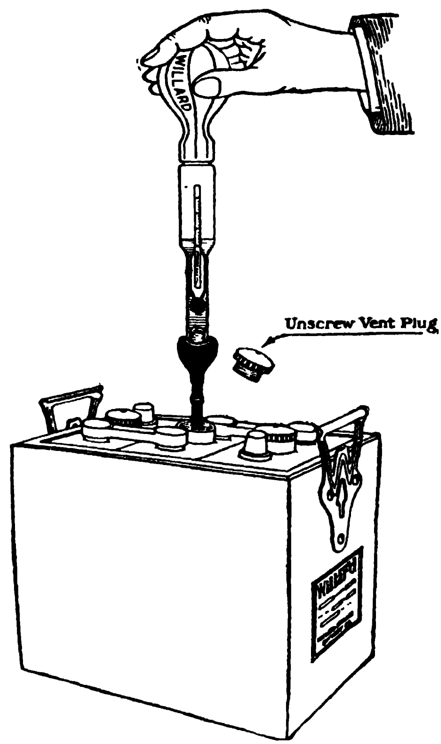


FIG. 1*b*.—Taking Hydrometer Readings.

The High-rate Tester is more accurate for storage battery testing. (See Fig. 1*c*.) Very often inexperienced battery men add acid to the battery fluid which in turn will indicate a high gravity when a hydrometer test is made, although the battery is not charged.

In Fig. 1*e* a pictorial diagram of the wires that carry the current through the wiring is shown. This diagram should be consulted when locating points at which loose connections in the primary circuits may be giving trouble.

A broken circuit means that one of the wires carrying a current is broken or a contact has become disconnected. The broken wire may lie between the battery and the switch, between the switch and the coil, or between the coil and the interrupter.

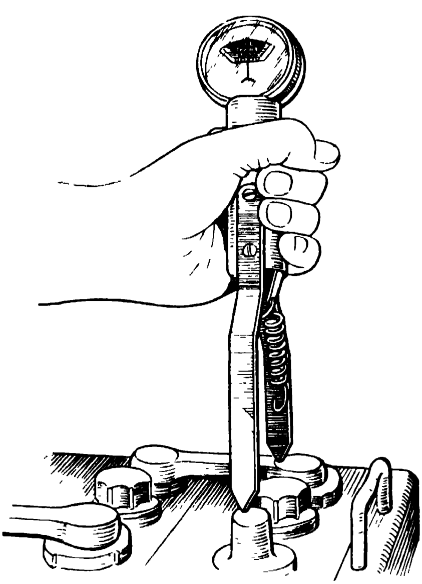


FIG. 1c.—High-rate Tester.

By examining all connections on the coil, ignition switch, and interrupter, a loose connection or a broken connection may be found. In case a loose connection is located, it should be cleaned and tightened.

If the insulation is broken on a wire, take a roll of friction tape and wrap a few layers around the damaged wire so as to restore the insulation. Shellac the tape when exposed at points where oil or grease may come in contact with it.

If a broken connection is located, it may be soldered as follows: Clean the wire thoroughly, by scraping away all rubber, and apply a small amount of non-corrosive soldering paste. Clean the wire terminal and sweat the wire to the terminal by allowing the melted solder to run on the wire. Broken wires are found, as a rule, where they connect to the other parts of the primary circuit.

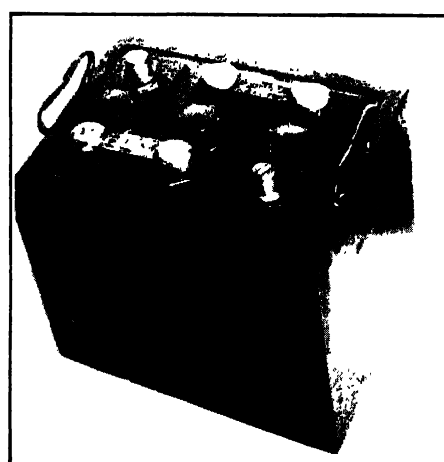


FIG. 1d.—The "Elm" Storage Battery.

On later cars little trouble is experienced with broken wires on account of the use of protective devices. Practically all the wires on the car are enclosed in a metal or fiber conduit which protects them from heat, oil, and water, and from becoming broken. It is evident

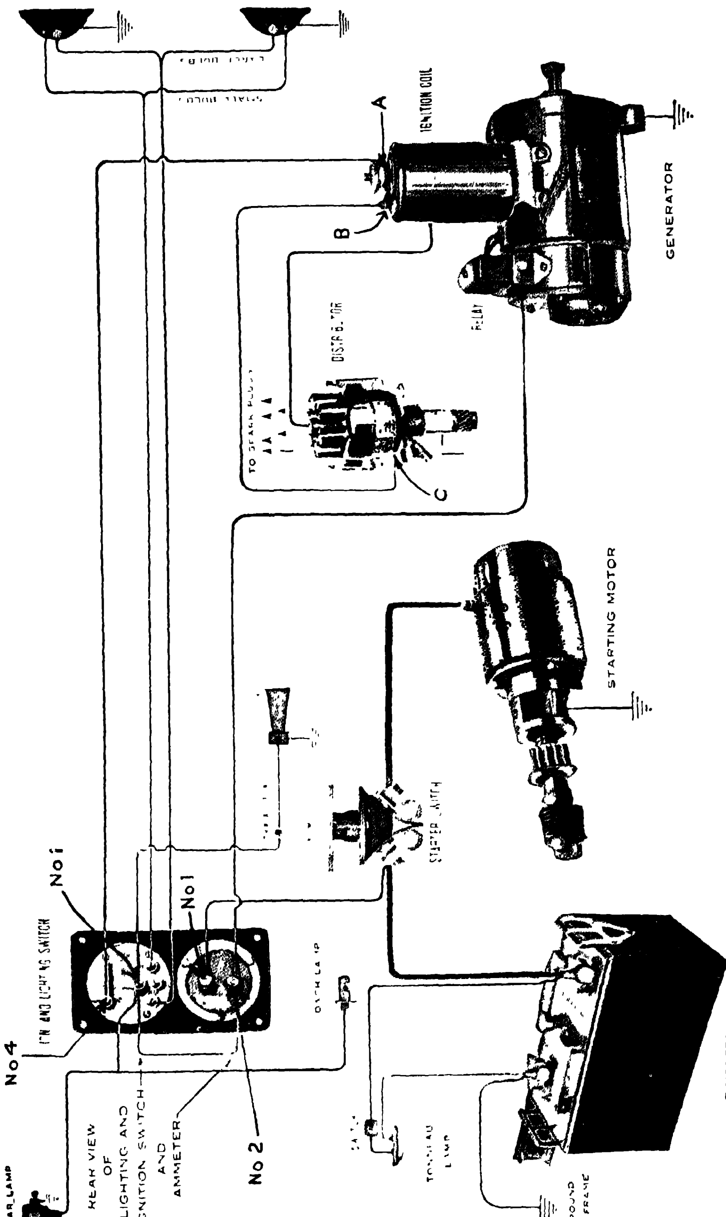


FIG. 1e.—Pictorial Diagram of Wiring System.

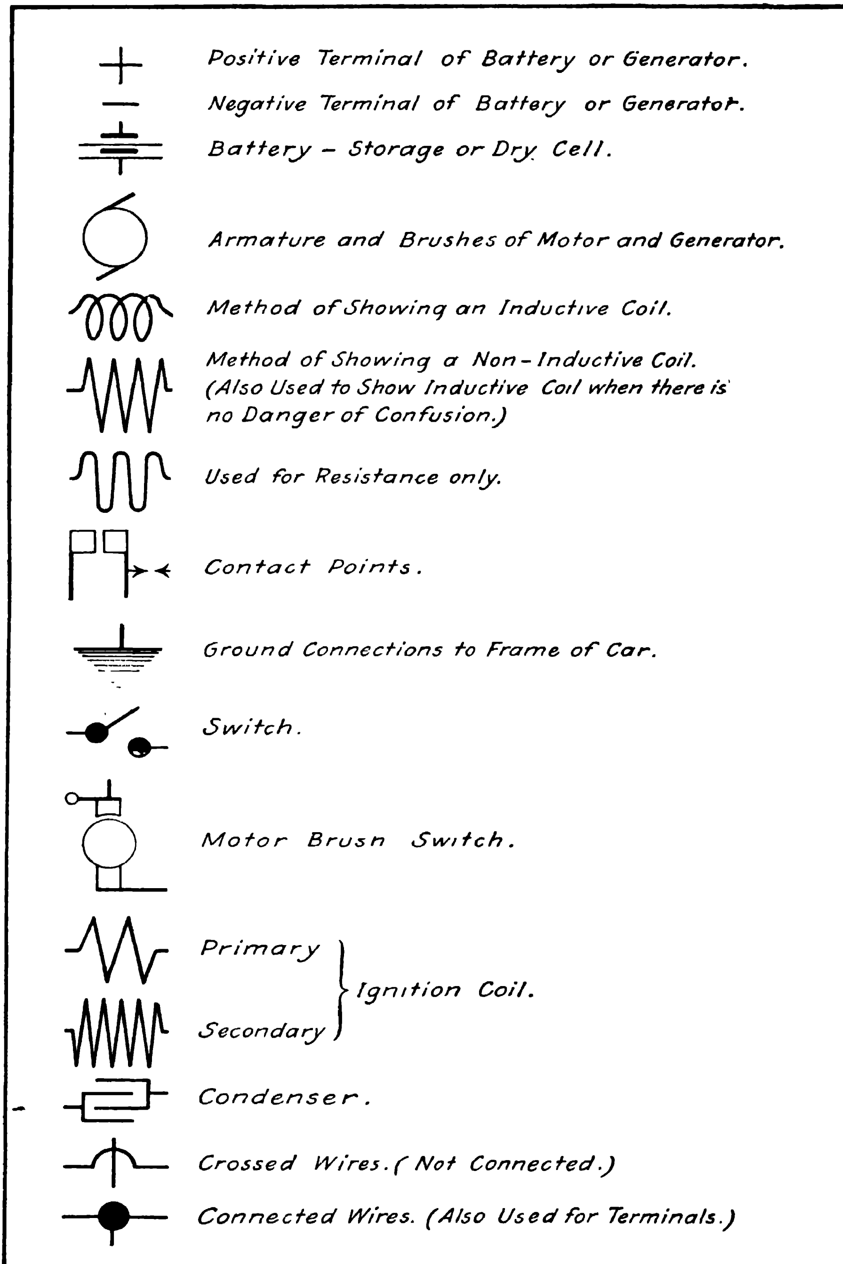


FIG. 1*f*.—Conventional Electrical Characters Used in Wiring Diagrams.

from this explanation that most wiring troubles will not occur in the conduits where they are difficult to locate and repair, but they will be found

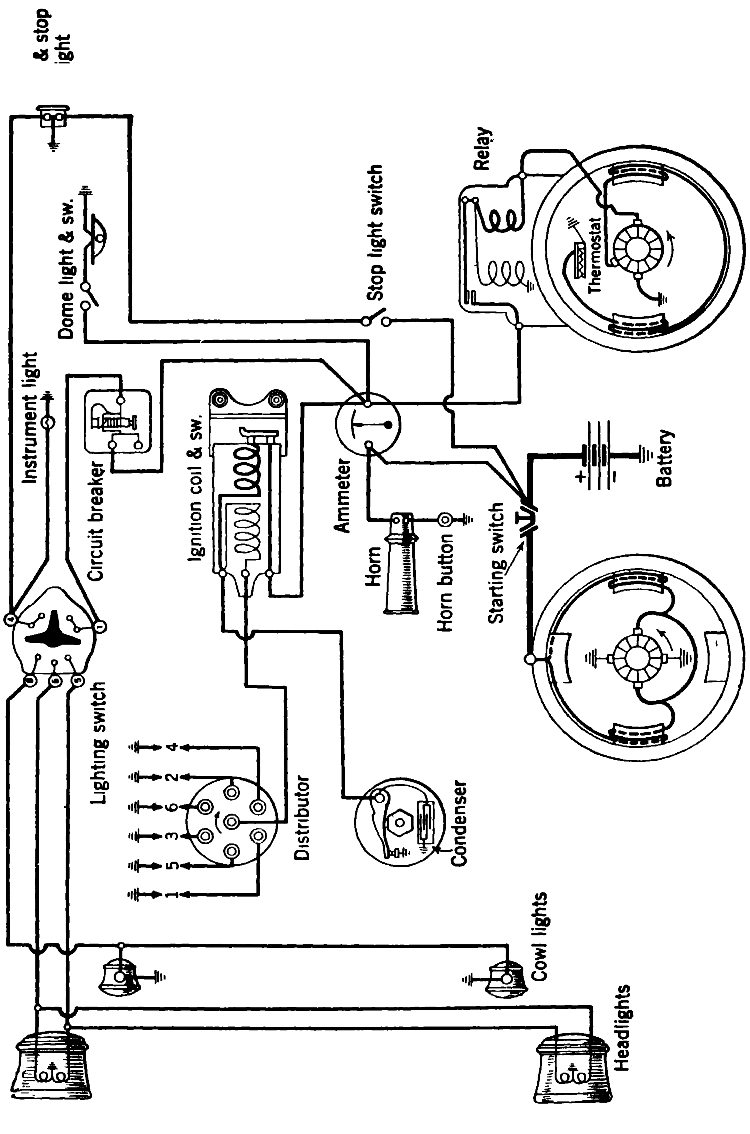


FIG. 1*g*.—Electrical Circuits. (Oldsmobile.)

where the external connections are made. In other words, the broken circuit will occur as a rule at points that are open for inspection.

If no broken wires or loose connections are found, the interrupter may

be improperly adjusted. (Refer to Fig. 3*e*, Job No. 3, for cut of interrupter.) The points should be adjusted so that when the cam strikes the breaker arm and opens the points they should be separated a distance specified by the manufacturer. (See Job No. 3.)

There is no set rule as to the correct air space between the interrupter points. Refer to the manufacturer's instruction book to get the exact setting.

If the points are readjusted, be very careful to lock them in position so that they will not come loose again. Check carefully for clearance between cam and breaker-arm fiber, when points are making contact. Do not adjust points so that fiber will make contact with flat side of cam when points are closed.

If the points are found to be pitted or rough, use a fine point file or carborundum stone to true them up. Care must be taken to keep the surface of the two points setting parallel to each other.

Figure 1*a* shows the primary ignition wires to be tested in case no loose or broken connections at exposed points have been found. Locate the battery, ignition switch, coil, and interrupter on the wiring diagram. This diagram is used only as an example to show the wires that carry the battery current through the primary circuit. Other wires are shown on the diagram in addition to the ignition wires. In testing for trouble in the primary circuit do not test the other circuits.

The wiring diagram also shows the relation of the wires in the ignition circuit to those in other circuits.

To separate the ignition wires from the other wires, locate the battery, ignition switch, coil, and interrupter. A 6-volt testing lamp for locating trouble should be a part of the repair-shop equipment. To use the lamp disconnect the battery wire which is fastened to the frame of the car. Fasten one side of the test lamp to the battery post (Fig. 1*e*). Touch the other test wire to the terminal on the ammeter marked No. 1. If the test lamp lights up, this part of the circuit is satisfactory. If the lamp fails to light up, there is a broken connection between the battery and No. 1 terminal on the ammeter.

Leaving one side of the test wire fastened to the battery post as before, touch the other test wire to No. 4 on the switch. If the test lamp lights up, the circuit through the switch is satisfactory. If the lamp does not light, the switch is defective. (See that the switch is "on" in making this test.) Examine the switch and tighten all loose connections. If the switch blades are found to be worn and in bad condition, install a new switch.

Now touch the test wire to the terminal, *A*, on the coil that is connected to No. 4 on the switch. If the lamp lights up, the circuit so far

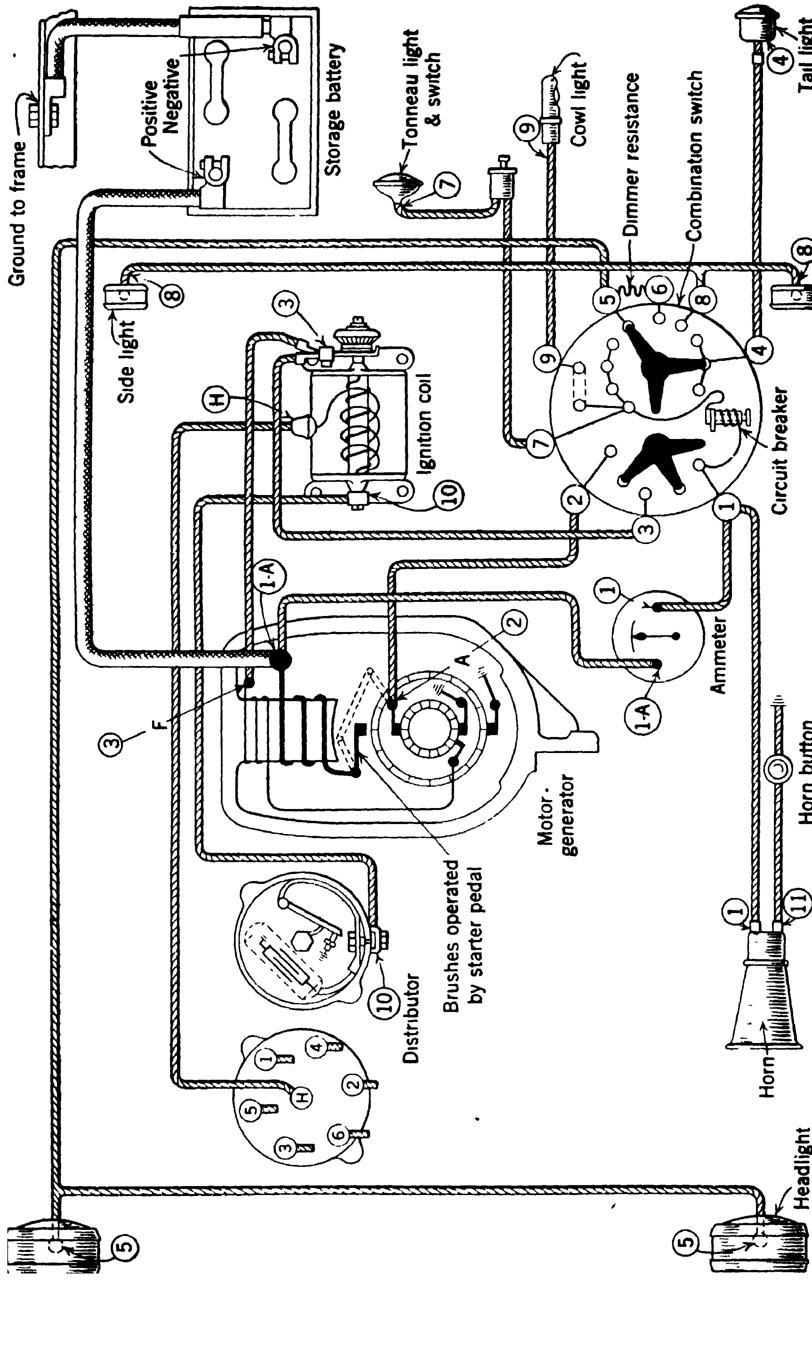


FIG. 1h.—Wiring Diagram. (Buick.)

is in good condition. If the lamp does not respond, the circuit is broken between No. 4 on the switch and the coil, and a new wire should be installed.

Now touch the test wire to the other terminal on the coil *B* that

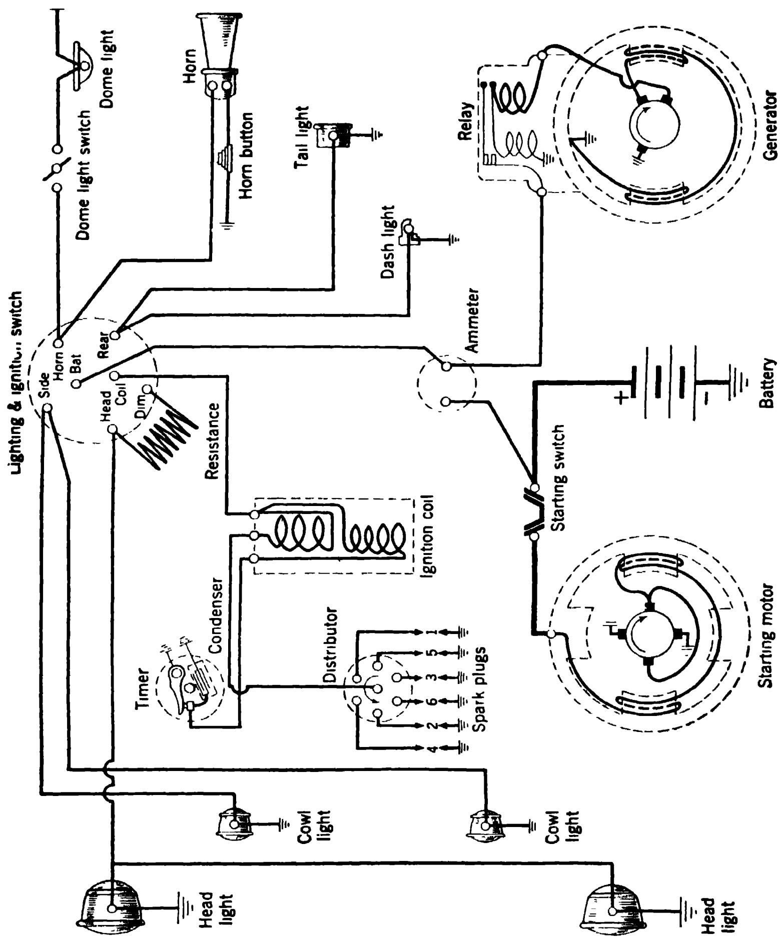


Fig. 1i.—Wiring Diagram. (P ntiac.)

connects to the interrupter. If the lamp does not light up, examine the resistance unit on the coil for a broken circuit.

If the resistance unit is found to be broken, connect a small wire from the post over which the resistance unit slips to the terminal on the coil to which the interrupter wire is attached. This is a temporary repair. The resistance coil should be replaced as soon as possible. For

the next step touch the test wire to the interrupter terminal. If the lamp lights up, the circuit is complete to this point. If the lamp does

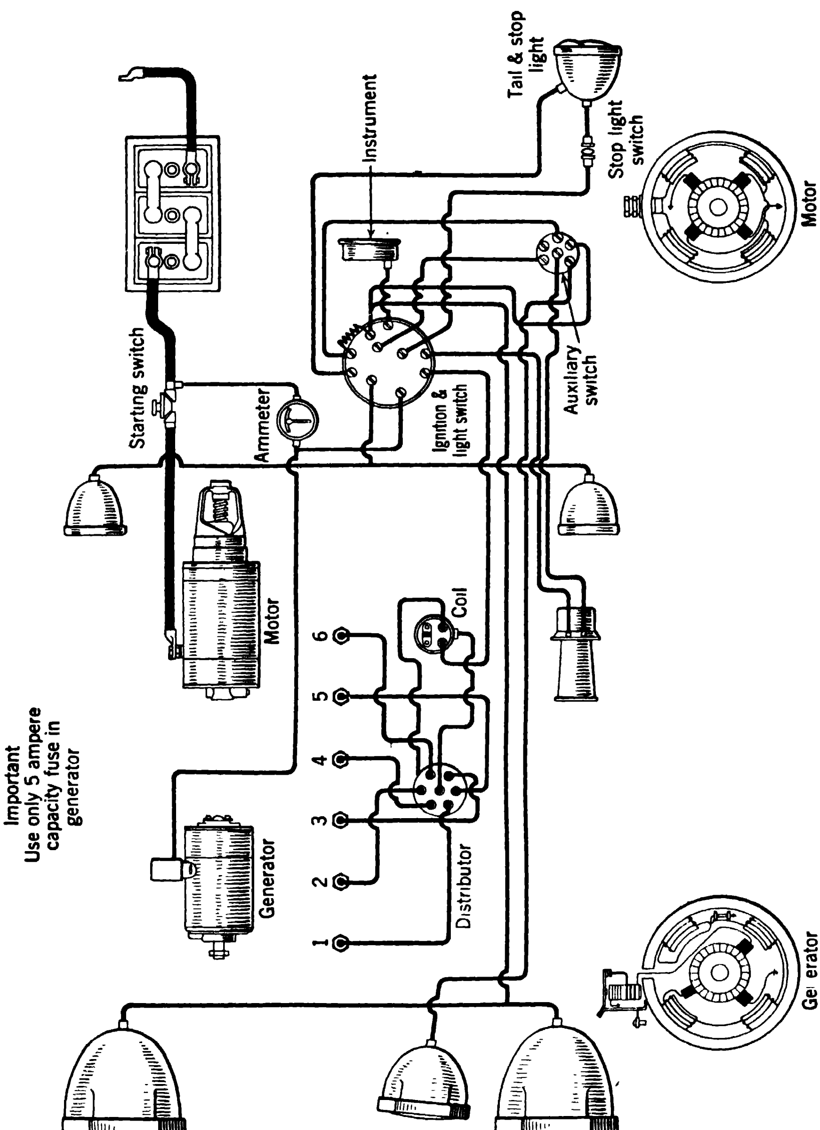


FIG. 1j.—Wiring Diagram. (Willys-Knight.)

not respond, the wire is broken between the coil and the interrupter and should be replaced. After replacing any part always repeat the test.

A very quick method of determining if there is any trouble in the primary circuit is to throw the ignition switch on and open and close the interrupter points by hand. If no flash occurs at the points, the primary circuit is broken.

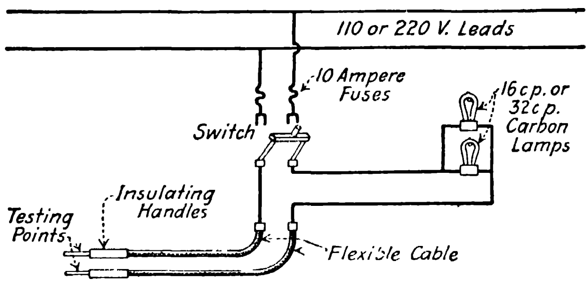


FIG. 1k.—110- or 220-volt Test Lamp.

If the broken circuit cannot be found by a careful examination, the wiring diagram of the particular car on which you are working should be consulted. The method of testing here described may be applied to any electrical system, but it should be kept in mind that other cars use different types of switches, coils, and interrupters and that they may not be found in the same order on all makes.

If the engine will not start, it is not always due to ignition trouble. See that the switch is on and that gasoline is reaching the carburetor, and test the battery as in Jobs Nos. 10 and 13.

If a condenser is connected to the interrupter, it may be tested with a 110-volt or 220-volt testing lamp (Figs. 1k and 1l).

A simple test for a condenser is to connect it to a 110- or 220-volt circuit, direct or alternating current, with a lamp connected in the circuit in series with the condenser. When the condenser is in good condition, there should be no current flowing through the circuit when the switch is closed, and the lamp should not light.

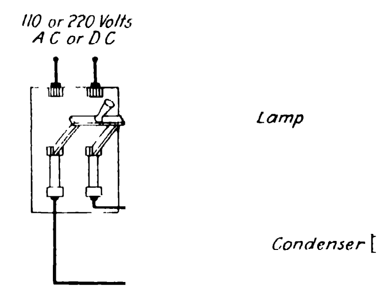


FIG. 1l.—Testing a Condenser.

If the lamp lights, the condenser is defective and should be replaced. A small spark will always be visible at test-lamp and condenser terminal when the circuit is broken, if alternating current is used.

Examine all connections from the condenser to the interrupter for a broken circuit. Restore the circuit if found broken. The condenser is usually found in the coil, and even if it were defective it could not be replaced without replacing the coil. Excessive sparking at the

circuit-breaker points or burned or badly pitted points indicates a broken-down condenser.

When doing any repair work on the car, care should be taken not to get against the cushions with greasy clothes. Place a large piece of canvas over the seat to protect the upholstery.

In making adjustments always refer to the manufacturer's instruction book for data on the particular model, since specifications differ on types and models.

Before starting to look for trouble in the ignition circuit get the location of the different parts of the ignition system through which the primary circuit must flow, and then find out by the method described why it does not flow.

Questions.

1. Name the different parts of the primary ignition circuit through which the battery current must flow.
2. What might happen to a battery that would prevent the current from flowing through the primary circuit? Give three things.
3. How would you determine the condition of "charge" in a battery?
4. How would you remove corrosion?
5. What would you put on battery terminals after removing the corrosion? Why?
6. What is a "broken circuit"?
7. Where is a "broken circuit" most likely to occur, and why?
8. Why do we run the wires through conduits?
9. Will it be possible to see all the wires on the car?
10. How will you repair a broken connection?
11. What trouble may we find in the interrupter?
12. How would you know the proper clearance between the points?
13. What care must be taken in filing or truing up points?
14. What is the last thing to do after points have been properly filed and adjusted?
15. How may you determine when there is trouble in the primary circuit?
16. If you examined all external connections where ignition wires are fastened to the switch, coil, and interrupter and found no loose or broken connections, what would you do next?
17. What is the value of a wiring diagram?
18. How would you attach a "test" wire to the battery when looking for a broken circuit?
19. How will you be able to separate the wires that carry the primary current through the ignition system from the rest of the wires on the car?
20. Describe fully how to proceed to locate the broken connections by the use of the 6-volt testing lamp.

21. How would you make repairs on a switch if it were found to be defective?
22. What trouble do we usually find in the switch?
23. Describe how trouble would be detected in a resistance unit?
24. How might you make a temporary repair on a resistance unit?
25. Where is the condenser usually found?
26. Describe a method for testing the condenser for a "short circuit" with a 110-volt line.

Job No. 2

TESTING COIL

References.—Part Two, p. 444.

Operations Necessary to Perform the Job.

1. If the entire ignition system has been checked, try a new coil to locate trouble.
2. If trouble is found in coil and is external, it may be repaired.
3. If trouble is found to be internal, use a new coil.

Care of Equipment.—Tag all wires and terminals before disconnecting. Do not try to open the coil. When removing wires care should be taken not to injure the terminals. Replace the coil with one of the same type. Keep the switch open except when testing the coil.

Description of Operations.

An ignition coil contains an iron core around which is wound several hundred turns of coarse cotton-insulated wire (Fig. 124, p. 441). On top of this primary winding are many thousand turns of fine wire. A condenser is found located in the coil or in the breaker box.

Melted wax is poured around the different parts to prevent moisture and oil from reaching the windings or the condenser. This wax makes it impossible to make repairs on the inside of the coil.

The current from the battery does not have sufficient pressure or voltage to jump the gap of the spark plug, and therefore the ignition coil which transforms the battery current into high-tension current is provided. The high-tension current is conducted by a heavily insulated wire from the terminal on the side or top of the coil to the center terminal of the distributor, which then directs the spark to the cylinders in the proper order of firing. The return circuit for the high-tension current from the spark plug is through the engine and metal parts of the car,

back to the metal base of the coil and sometimes by means of the primary winding of the coil.

If total failure of spark cannot be traced to poor wiring connections or dirty circuit-breaker points, examine the resistance wire on the coil and see if it is intact.

To test for spark failure apparently due to the ignition coil, first determine if the current is reaching the coil. With the breaker points closed, remove the primary wire leading from the coil to the breaker box. Place ignition switch in "On" position. Take lead removed from breaker box in hand and make contact with metal part of engine or distributor. A spark will occur at point of contact, if circuit is complete. Next touch the free end of the wire to its breaker-box terminal and a spark should occur at that point. Open the breaker points and repeat. No spark should occur at this time; if it does, the condenser, if located in breaker box, is short-circuited or the breaker-box insulation is defective. If there is no flash to indicate a current, there is evidently a loose connection or a ground in the primary wiring outside the coil.

If the flash occurs the coil windings may be tested by closing and opening the circuit-breaker contacts by moving the lever quickly with the fingers, using care not to spring the lever in any way. While this is being done hold in contact with the base of the coil a wire or metal piece with one end within $\frac{1}{8}$ inch of the high-tension side terminal of the coil. A spark will jump across the gap when the coil is in good condition.

A further test of the coil primary or low-tension winding may be made by connecting a lamp (Fig. 1*k*) in series with 110 volts across the two terminals on the end of the coil, with the ignition turned off. If the lamp lights, both the coil winding and the resistance unit are all right. If one of the testing wires is connected to the base of the coil or one of the primary terminals, depending upon the type of coil, and the other is brushed across the side terminal, a small spark indicates that the circuit of the secondary or high-tension winding is complete. This secondary winding is of such high resistance that even 220 volts would not light a lamp in series across its terminals.

If the entire ignition system has been checked and no broken connections or wires are found and the switch, battery, and interrupter are in good condition, and no spark at the plugs is obtained, try a new coil. If the old coil is found to be defective, replace it with a new coil of the same capacity.

Questions.

1. Why is it unnecessary for the general repairman to know what is in the coil?
2. May we make any repairs on the inside of the coil? Give reasons.

3. How may we determine when a coil is defective without testing it?
4. Of what practical value would it be to test out a coil?
5. What must be done before removing a coil?
6. Is it necessary to use a test coil of the same capacity as the one being tested?
7. Can a 6-volt coil be used on a 12-volt system, or *vice versa?*

Job No. 3

TIMING IGNITION

References.—Part Two, Chapter XI.

Operations Necessary to Perform the Job.

1. Check flywheel marks with piston position, to find out if they coincide.
2. Test interrupter for time of opening with marks on flywheel.
3. If "not in time" reset "in time," according to manufacturer's instruction book.

Names of Parts, and Operations to be Reviewed before Performing the Job.

Parts.—Distributor breaker, breaker arm, breaker-arm point, fixed breaker point, distributor brush, distributor shaft, distributor shaft-gear, ignition coil, ignition switch, spark-control rod.

Operations.—Timing, resetting, or replacing ignition.

Locations.—" Flywheel markings," " dead center."

Description of Operations.

The time at which the spark occurs in the cylinders, relative to the travel of the pistons, is controlled by the advance and retard features of the contact maker. A spark is produced at the instant the contact points open, and the time at which they separate is advanced or retarded by the governor and also by the spark lever on the steering column.

There is a certain point in the travel of the piston, depending upon the engine speed, at which the occurrence of the spark produces the maximum efficiency. Ordinarily, the spark occurs and the consequent combustion of the ignited charge starts just before the piston reaches the highest point of its stroke. However, if the spark is too far advanced for any given engine speed, the effect of the combustion is exerted

before the piston reaches its highest point and the result is a considerable loss of power in addition to the presence of a " spark knock."

If the spark is too far retarded for the speed of the engine, the maximum effect of the combustion is exerted so long after the piston passes its highest point that some of its energy is wasted and, not being applied mechanically, tends to overheat the engine.

Manufacturers of different types of automobiles treat the timing of the ignition system in different ways. One car manufacturer states that the spark should be fully advanced on the quadrant with the piston in a specified position before top dead center. Others specify that the

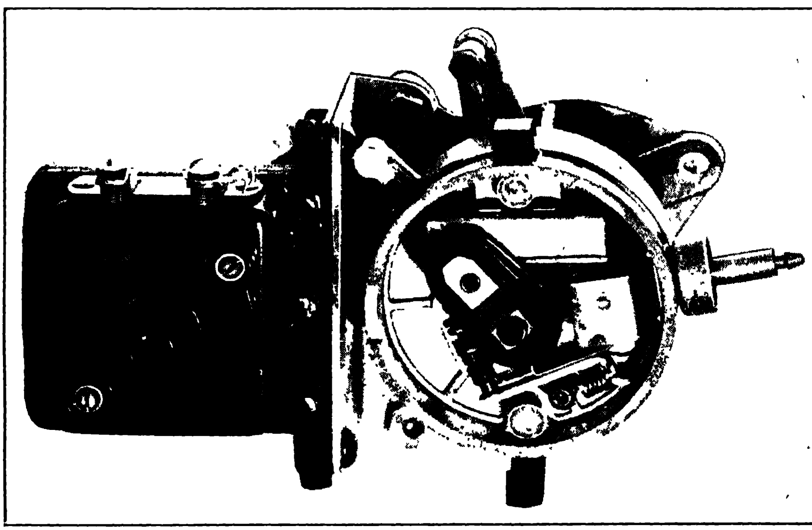


FIG. 3a.—Ignition System. (Franklin.)

points should be about to separate with the spark lever at full retard and the piston on dead center, or a few degrees past, before this position is reached.

Each cylinder has two valves, namely, the intake and the exhaust. The repairman must be able to distinguish between them in order to find the proper firing order of an engine. He can usually tell when a piston is coming up to top dead center at the end of the compression stroke, by putting his finger over the priming cock or the spark-plug hole of the cylinder while turning the crank, since the piston will force the air out of the cylinder around the finger. This method is not of much avail, however, when a reconditioned or tight engine is to be timed. It is of vital importance that the passage through the priming

cock, if this method is used, be free from obstruction, usually caused by the accumulation of carbon or foreign substances.

When a repairman is about to time the ignition system of a motor which has just been overhauled, and which, therefore, will be reasonably tight, he must first determine the firing order. The procedure is carried out as follows: Observe both valves of the first cylinder while turning the starting crank. As the crank turns, one valve will open and close; and before the crank is moved a small fraction of a revolution beyond this point, the other valve will open. *The valve that opens immediately after the other valve closes is the intake valve.* After the intake valve closes, the crank must be turned almost a full revolution before the exhaust valve will open. In this manner check the valves of each cylinder, designating the intake or exhaust valves with a chalk mark. After all valves have been checked, turn the crank until No. 1 intake valve opens. Again turn the crank slowly and note the next intake valve that open.

Proceed in this manner until all intake valves have opened and closed. This procedure will require two complete turns of the crank shaft. The sequence in which the intake or the exhaust valves open is the firing order. As the next step place one end of a secondary wire on a spark plug and connect the other end to the distributor head according to the firing order. The secondary wires must follow around the distributor head in the direction of the cam rotation.

Check the setting of the breaker points according to the manufacturer's instruction. An air-gap of 0.006 to 0.020 inch will be found the average opening for most systems. Close the points and check the clearance between the cam and the breaker-arm fiber. The clearance should never be less than 0.008 inch. The operator should now replace the distributor cap and observe the position of ignition contact when connected with No. 1 spark plug (cylinder next to radiator). As the next step, remove the distributor head and observe the position and direction of rotation of the rotor and cam.

Spark settings are usually made when the spark lever is in a retarded position. Therefore it is very important that the repairman know when the spark is advanced and when it is retarded. Two types of advance and retard controls are generally used. The most common type moves the breaker arm against or away from the direction of rotation of the cam. When the breaker assembly moves in the opposite direction to that in which the cam rotates, or against the direction of rotation of the cam, the spark is advanced. When the breaker box is moved in the same direction as that in which the cam rotates, the spark is retarded. The second method is accomplished by moving the cam.

If the cam is turned in the direction of rotation, the spark is advanced. If the cam is moved in a direction opposite to that of rotation, it is in a retarded position.

The top dead center at the end of the compression stroke may be found by turning the crank until No. 1 cylinder intake valve opens and closes. The crank should then be turned slowly until the piston reaches the highest point in the cylinder. This operation will require slightly less than half a turn of the crank. In a six-cylinder engine, No. 6 exhaust valve will just close at this point; and in a four-cylinder engine, No. 4 exhaust valve will just close. This position of "top dead center"

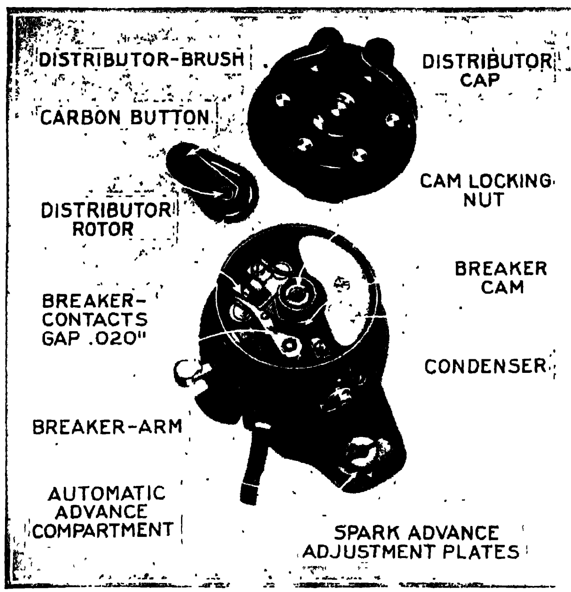


Fig. 3b.—Distributor with Cap Removed.

should now be checked with the flywheel marks. Very often flywheels are removed and are not replaced in the same position as when they were marked. Flywheel marks are reached by removing the floor boards and the flywheel inspection plate, and in some types by openings at the forward side of the flywheel case (see Fig. 3d, p. 170). In this position place the rotor directly under contact connected with the wire leading to No. 1 spark plug and set the cam so that it is just about to open the breaker points, with the spark retarded. With all parts in these positions, lock the adjustments or tighten the cam and prepare to start the engine. When a gear mesh is changed, always inspect the gears to see that they are thoroughly lubricated and in a serviceable condition.

When timing an ignition system employing an automatic advance and no manual control, set the points so as to open at " top dead center."

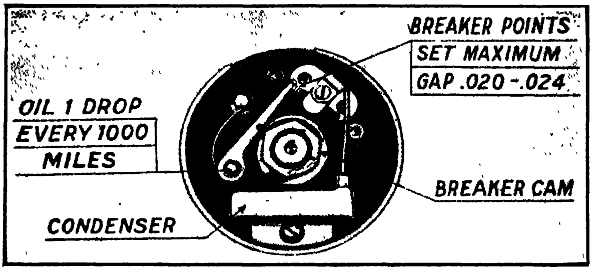
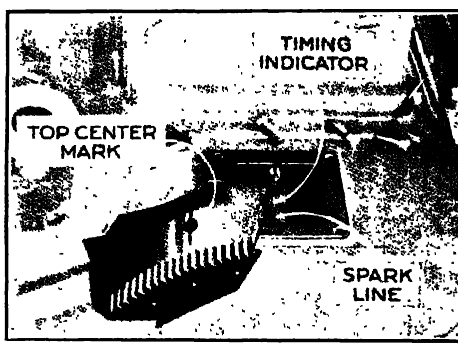


FIG. 3c.—Breaker Box. (Auto-lite.)

Adjustment of Atwater-Kent System.—The only part of the Atwater-Kent System which is adjustable is the contact holder in the unisparker, and this is adjustable only for the natural wear of the contacts. The initial adjustment at the factory should not require changing for many thousands of miles, the wear being practically negligible.

Contact Points.—The normal gap between the contact points should be 0.008 inch. When the contact points are working properly, small particles of tungsten will be carried from one point to the other, sometimes forming a roughness and a dark gray color on their surfaces. This roughness does not in any way affect the proper working of the points, owing to the fact that the rough surfaces fit into each other perfectly. It should never be necessary to dress down these points. If it is suspected that they are causing missing by reason of being dirty, they may be cleaned by gently scraping with a pen knife or drawing a point



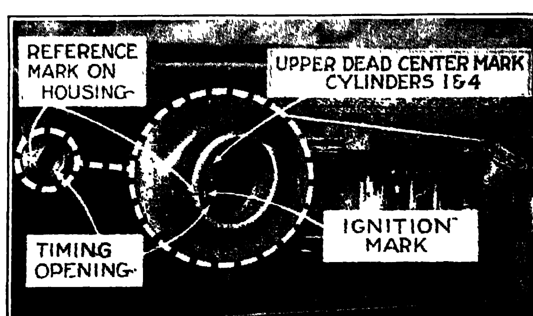


FIG. 3d.—Locations of Flywheel Markings.

file between them. It should be remembered that although the contact surfaces are very rough, they may be in perfect working condition, the dark gray appearance being the natural color of the tungsten.

Adjusting Timing Contacts. (Fig. 3*e*, Delco.)—The timing contacts should be adjusted so that when they are opened by the breaker cam they are separated by the thickness of the gauge on the distributor wrench marked " Distributor." This is 0.018 inch. Owing to the wearing to a seat of the fiber bumper on the breaker cam, this will require one or two adjustments during the first season's driving, after which practically no further attention is necessary. The timing contacts are

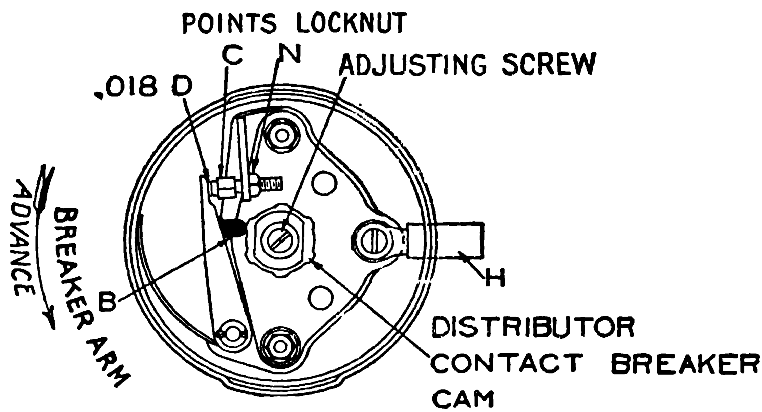


FIG. 3*e*.—Delco Ignition Distributor Breaker or Interrupter.

tungsten metal. They are very hard and should require no other attention than to maintain the proper adjustment.

Questions.

What is meant by timing the ignition?
For what purpose is the flywheel marked?
Why are the valve gears marked?
Why does the manufacturer go to the expense of putting out a hand book on the timing of the ignition and on making other adjustments?
Will the timing rules for one car work on all cars?
What trouble will result if the ignition is incorrectly set?
If the radiator has been taken off to reach the timing gears, what must be done after the hose couplings are fastened to the radiator?
If it is necessary for a repairman to sit in the seat of the car, what precaution should be taken?

9. At what time should the spark occur when the engine is cranked?
10. When it is running?

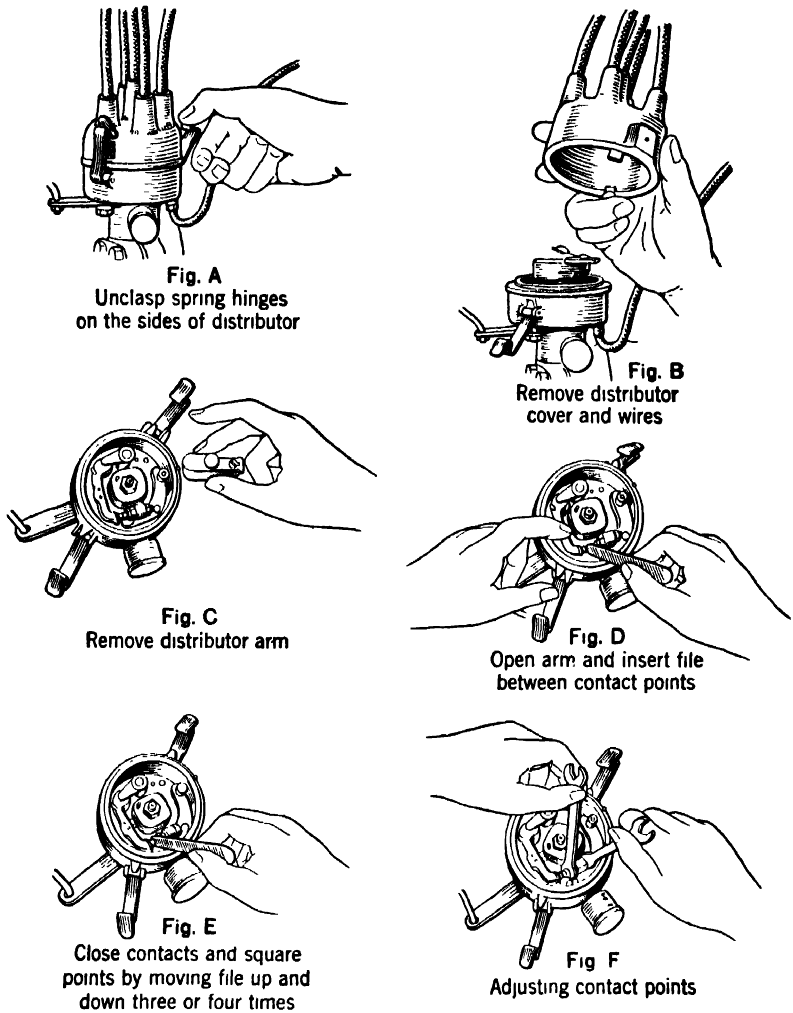


FIG. 3f.—Disassembling Igniter Distributor. (Chevrolet.)

11. What is meant by advancing and retarding the spark?
12. What difference will be made in setting the spark lever in cranking the car by hand, when using the battery and when using the magneto?

Job No. 4.

CLEANING SPARK PLUGS

Operations Necessary to Perform the Job.

1. Disconnect high-tension wires.
2. Remove spark plug.
3. Remove carbon.
4. Inspect porcelain and gasket.
5. Replace with new gaskets if necessary.
6. Adjust points.
7. Replace spark plugs and high-tension wires.

Description of Operations.

Spark Plugs.—The spark plug forms a set spark gap in the cylinder, across which the spark jumps to ignite the charge of gasoline vapor and air which is drawn in through the carburetor. The plug consists of a metal shell which is screwed into the cylinder, and an insulated metal electrode in the center through which the current from the spark-plug wire travels. The spark is caused by the jumping of the current from this electrode to the connection from the outer shell, through which the current returns to the engine, the frame of the car, and the coil. The gap between the sparking points of the plug should be from 0.020 to 0.030 inch, depending on the type of ignition (Fig. 4*a*). Too wide a gap will cause the motor to start hard and to miss on a heavy pull at slow speed; and too narrow a gap will cause missing when the motor is running at high speed, when a magneto furnishes the current. Spark-plug points set too close, when a battery-breaker system furnishes the current, will cause a miss at very low speeds.

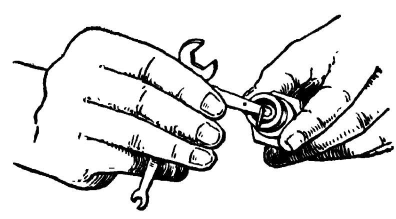


Fig. 4*a*.—Adjusting Spark Plugs.

The condition of the spark plugs can be ascertained by holding a screw driver with the point on the top of the cylinder, and allowing the shank to come in contact with the terminal of the plug. Hold the screw driver only by its wooden handle to avoid a shock. Place the end of the screw

driver on the cylinder first. If the engine has already been missing on the cylinder tested, no change in its operation will be noticed when the plug is thus short-circuited, and the missing will therefore be traced down to the cylinder tested. The spark which jumps from the terminal to the screw driver will be shorter when the plug is fouled or shorted. To make sure that the current is actually coming to the plug, remove the wire and hold the terminal within $\frac{1}{8}$ inch of the body of the plug while the engine is running. If a spark is observed between the terminal and the plug, the fault is in the plug itself.

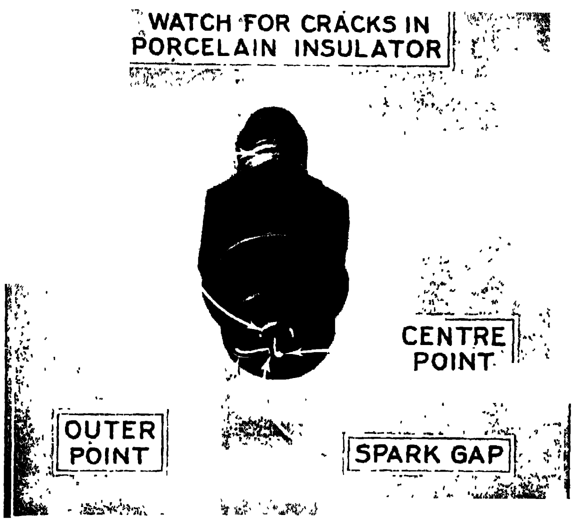


Fig. 4b.—Parts of a Spark Plug.

Spark-plug failure may be due to the collection of carbon on the sparking points, breaking or cracking of the insulation or porcelain, or fouling with oil and soot. In the last case the porcelain should be thoroughly cleaned.

To clean and adjust, remove the high-tension wires, being careful to keep in mind the way they come off so as to put the same

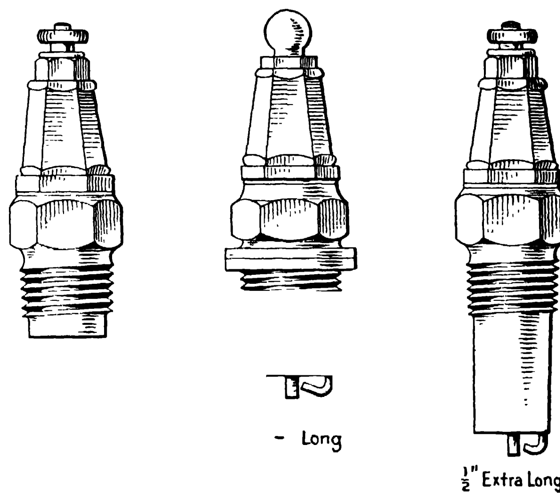


Fig. 4c.—Types of Spark Plugs.

wires back on the same plugs. Remove the plugs with a spark-plug wrench and take the plug apart if it is of the two-piece type. Be very careful not to let the wrench slip and break the porcelain.

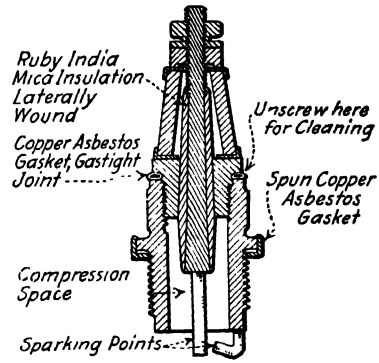


FIG. 4d.—A Section View of a Spark Plug.

Saturate a rag or some waste with gasoline and wipe the porcelain clean. If any burned oil stays on the porcelain, do not scrape it off with a knife, as this scrapes off the glaze, making it porous. Use a wire brush or saturate a rag with muriatic acid, metal polish, or alcohol for one-piece plugs, and cut off the burned oil without damaging the porcelain. Paint remover will also cut the carbon. Scrape the carbon from the spark-plug shell and inspect the gaskets. Examine the porcelain for cracks. See that the wire running through the porcelain is not loose.

After cleaning, reassemble the spark plugs. Adjust the points

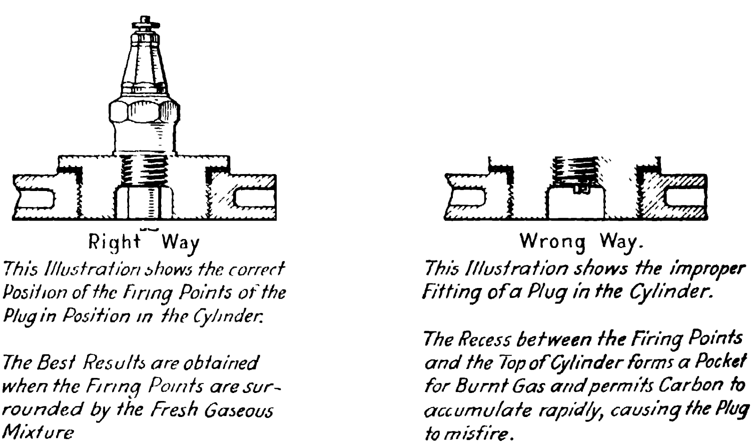


FIG. 4e.—Selecting a Spark Plug.

according to the manufacturer's instruction book for the particular car on which the plugs belong.

It is a good plan to put a small amount of a mixture of oil and flake graphite on the threads when replacing the plugs, to make them easy to remove in the future. When ordering new plugs, order the plug with the

same thread and of the same length (see Figs. 4*c*, 4*d*, and 4*e*). A ½ inch pipe-thread plug uses no gasket. The metric and ⅞-inch spark plugs use gaskets.

Questions.

1. Before removing the spark-plug wires, what precaution should be taken?
2. How will you clean the porcelain, if the carbon is burned on?
3. What examinations should be made when the spark plug is cleaned and ready to be reassembled?
4. How will you adjust the points after the parts are all reassembled?
5. After the spark plugs are replaced in the car, what tests should be made?

Job No. 5.

REPAIRING DISTRIBUTOR

References.—Part Two, pp. 448-9.

Operations Necessary to Perform the Job.

1. Inspect distributor for defects such as cracks, worn or uneven surface, excessive oil, or carbon dust.
2. Inspect points in distributor.
3. If defective, replace distributor.

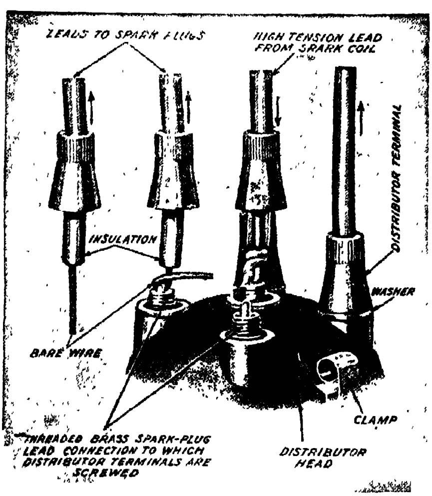


Fig. 5*a*.—Showing Method of Connecting High-tension Leads to Distributor Cap of Igniter.

Description of Operations.

Inspect the distributor (Fig. 5*a*) for cracks and replace it with a new one if any are found. Examine the terminals on the outside of the distributor for loose connections. Inspect the inside of the distributor cap for rough or uneven surfaces and replace it with a new cap if it is defective.

Figure 5*b* shows how to remove a defective breaker plate and how to replace a new plate on the Connecticut System.

The only repairs that may be made on the distributor are to tighten a loose connection or to clean the inside and outside surfaces of the distributor with a rag dampened with kerosene.

Never allow carbon dust to accumulate in the distributor, as the spark may go to some other cylinder than to the one on compression. If the

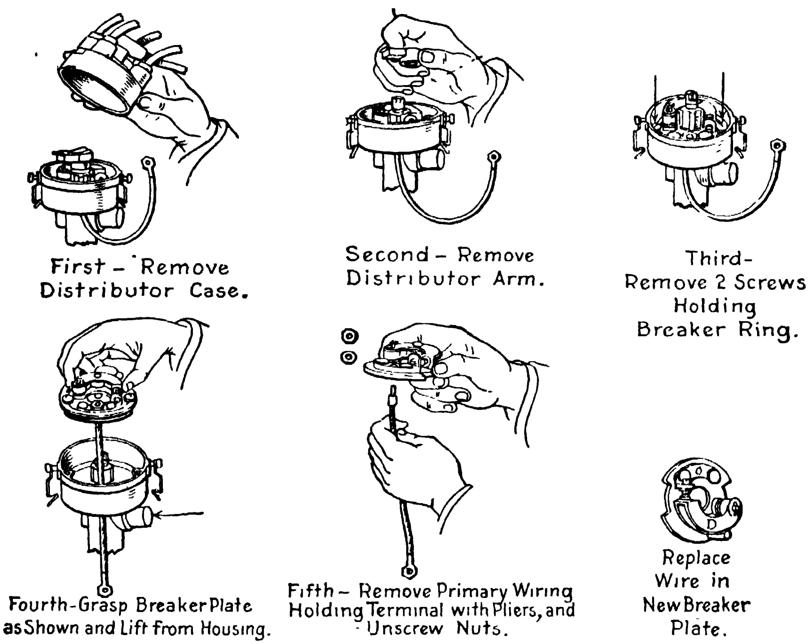


FIG. 5b.—Replacing Breaker Plate.

distributor wires are removed, make certain to replace them in the same position.

Questions.

1. Is it a good policy to attempt to repair a cracked distributor cap or one that has a rough surface? Give reasons.
2. What repairs may be made to a distributor?
3. What trouble may result from carbon dust on the inside of the distributor?
4. Before removing the distributor wires, what precaution must be taken?
5. What wires connect to the distributor?
6. How may a spark be produced without turning the engine over?
7. If the secondary wire which carries the secondary current (or spark) from the coil to the middle of the distributor is detached and con-

tinued attempts are made to start the engine or to produce a spark, what may be the result to the windings on the inside of the coil?

8. What is the purpose of the distributor?

Job No. 6

TESTING AND REPLACING MECHANICAL PARTS OF IGNITION SYSTEM

References.—Part Two, pp. 444–461.

Operations Necessary to Perform the Job.

1. Test gears, bearings, and shafts for excessive wear resulting in "lost motion."
2. If "lost motion" is too great, replace worn parts.
3. Replace new parts and time.

Description of Operations.

"Lost motion" in the gears or the housing surrounding the interrupter shaft causes an irregular opening of the interrupter points. To

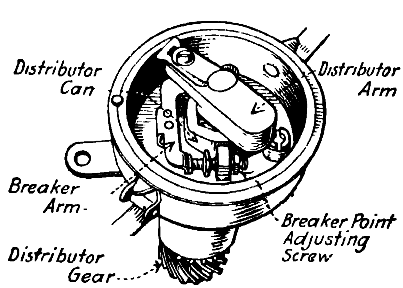


Fig. 6b.—Circuit-breaker and Distributor. (Remy.)

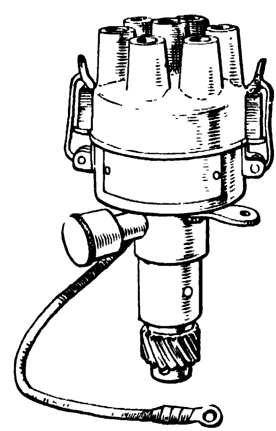


Fig. 6c.—Lubricating the Distributor Shaft.

test for "lost motion," turn the engine over until the interrupter points close. Now push the cam that opens the points back and forth and watch the points to see if they open. If they do there is too much play and a new bushing or housing will need to be installed

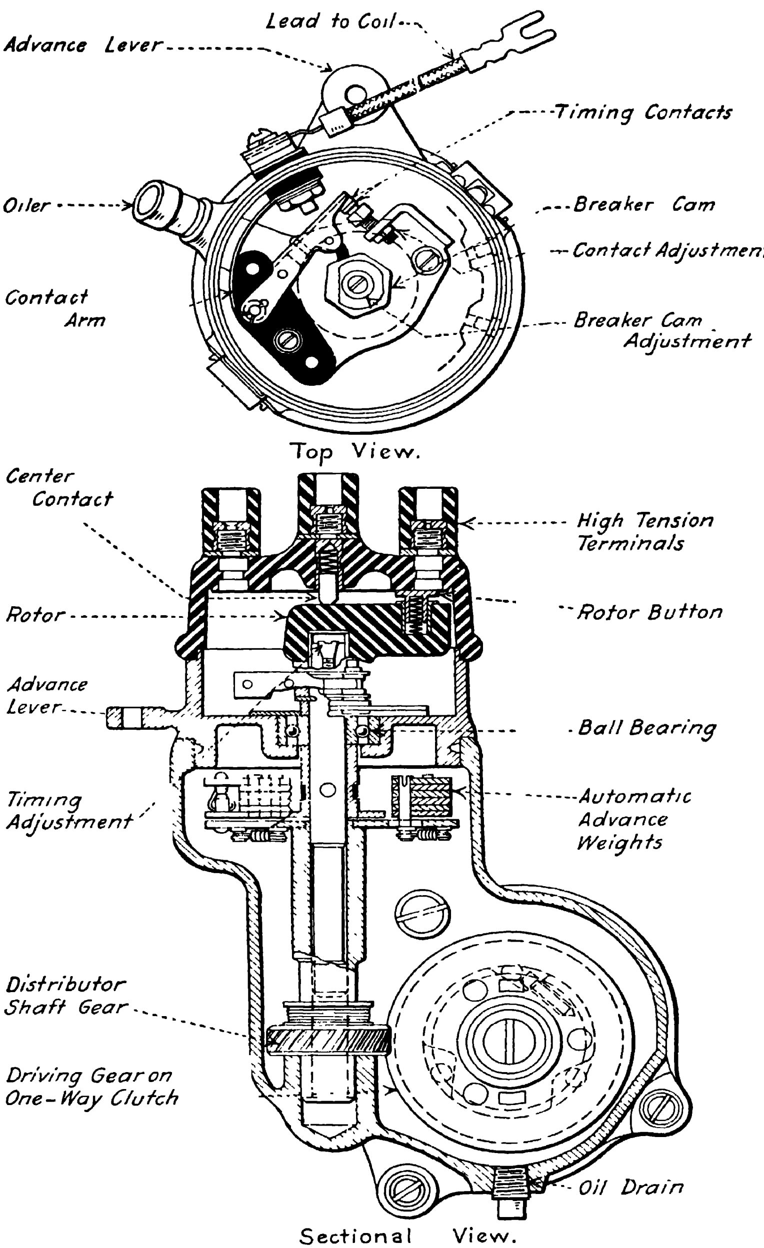


FIG. 6a.—Sectional View of Distributor. (Buick.)

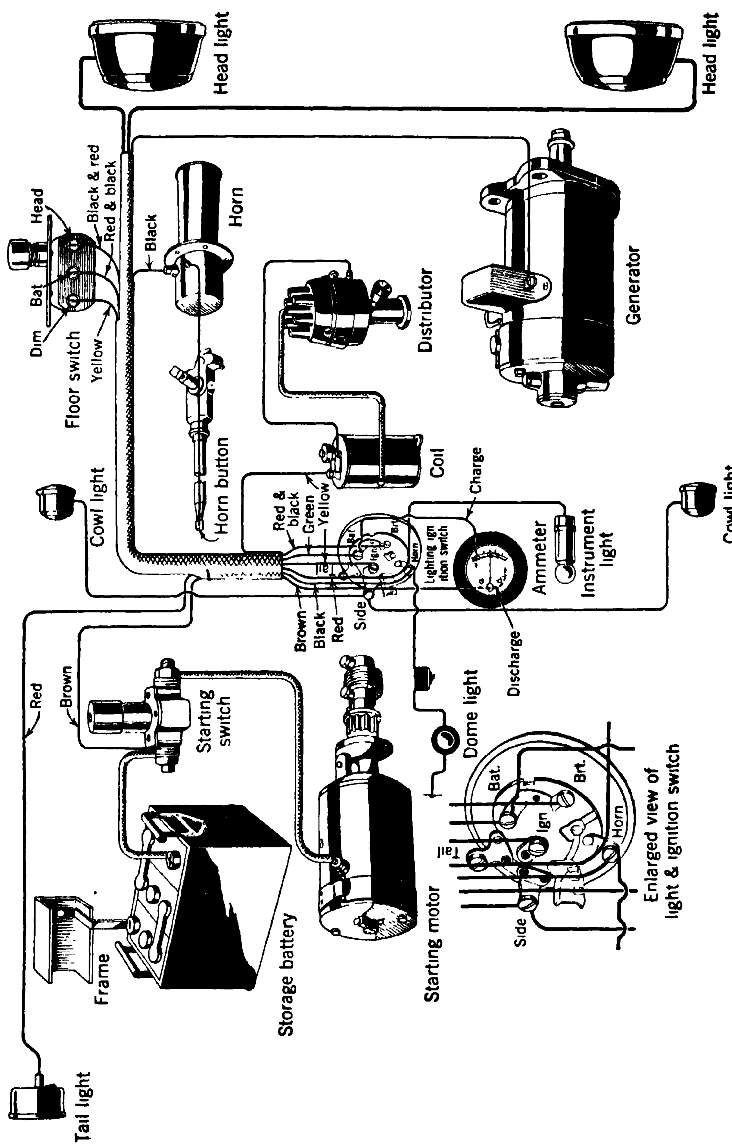


FIG. 6d.—Wiring Diagram. (Oakland.)

Next test for loose play in the gears. To do this attempt to turn the cam first to the right and then to the left. It should have a little play, but if the play is excessive new gears must be installed.

Before removing any gear, shaft, cam, or part, always make a small mark on the parts so as to set the new part in correct time.

Each spark plug of the engine is connected by a heavily insulated wire to one of the terminals on top of the distributor cap. The center terminal, to which is attached the high-tension cable from the ignition coil, has a carbon or metal point (see rotor button, Fig. 6a) on the under side of the cap, which makes electrical contact with the rotor or segment. The rotor fits upon the shaft only in the one correct position relative to the cam, so that, as it rotates, it always comes opposite the correct extension in the cap to conduct the spark to the proper cylinder when the cam separates the circuit-breaker contact points.

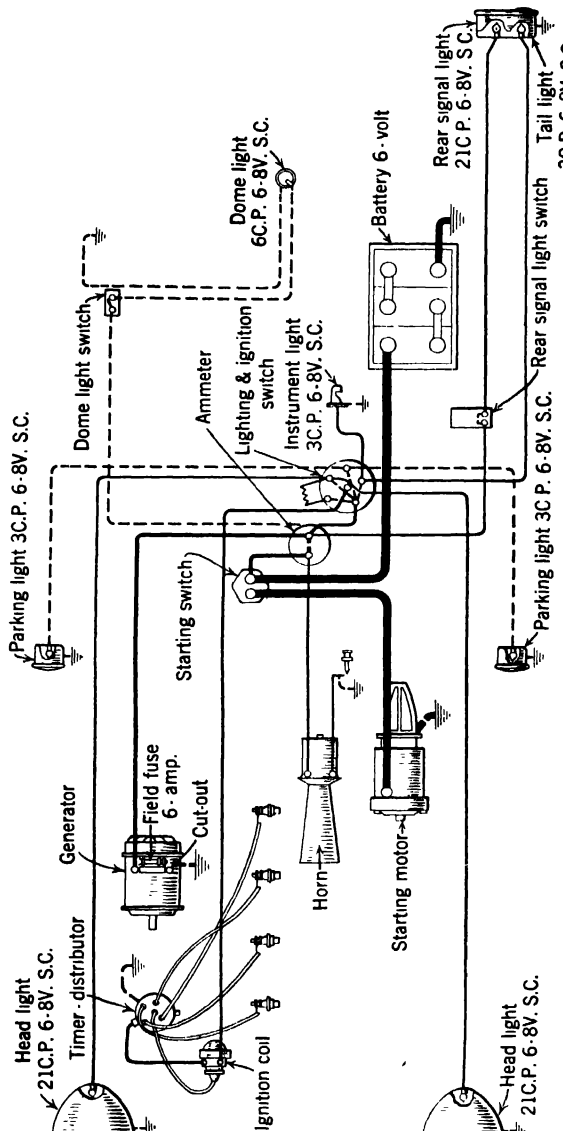


FIG. 6e.—Two-unit System. (Dodge.)

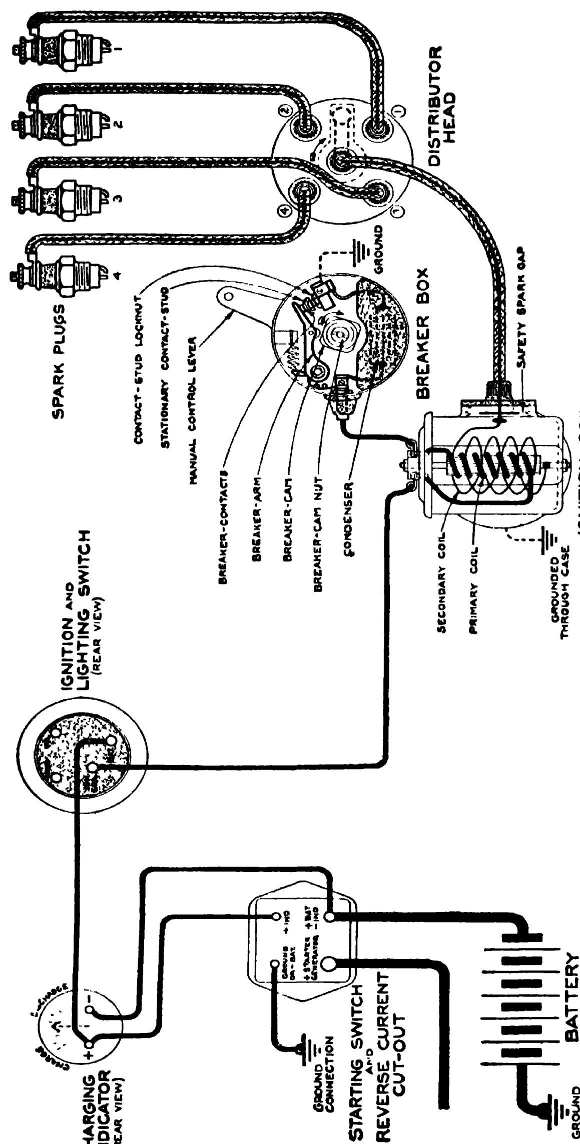


Fig. 6f.—Circuit Diagram Ignition System. (Dodge.)

The distributor (Fig. 6c) is provided with a grease cup, which should be kept full of medium grease and turned to the right two or three turns every 1000 miles of running, to force a little grease into the bearing. A drop of oil should be placed on the lobes of the cam every 2000 miles.

Questions.

1. Describe a method for testing for "lost motion" in the gears and bushings.
2. What trouble will be experienced on account of "lost motion"?
3. What precaution must be taken before removing any parts that control the opening of the interrupter points?
4. What tests should be made if any new parts have been installed?
5. What will be the result of a deposit of metal or carbon dust in the distributor?
6. What are the different names applied to the circuit-breaker?
7. How is the current distributed on a Ford ignition system?

Job No. 7

REPAIRING A MAGNETO

References.— Part Two, pp. 456-60.

Operations Necessary to Perform the Job.

1. Examine interrupter for ignition trouble.
2. Adjust or replace parts found to be defective.
3. Check magneto alignment.
4. If trouble is not located in above, send magneto to service station.

Names of Tools and Parts to be Reviewed before Performing the Job.

Tools.—Set of magneto wrenches and set of socket wrenches.

Parts.—Magneto, distributor, breaker box, breaker arm, fixed breaker point, breaker-arm point, distributor brush, collector spool, ground brush, safety spark gap, collector-ring brush, magneto-coupling pump end, magneto coupling center member, magneto-coupling magneto end, impulse starter coupling.

Description of Operations.

It is not necessary that the repairman have a broad understanding of the theory of a magneto in order to do any repair work that may

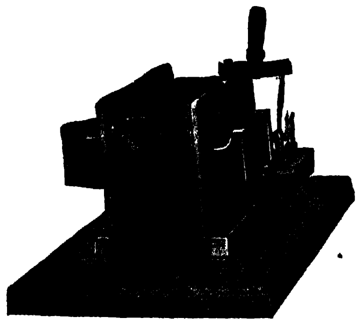


FIG. 7a.—Magnet Charger. (Splitdorf.)

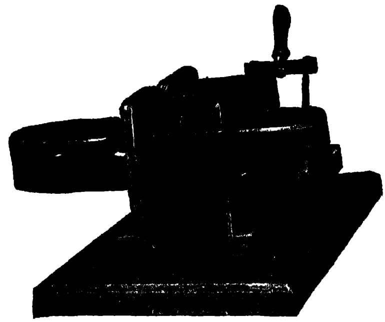


FIG. 7b.—Inserting the Magnet.

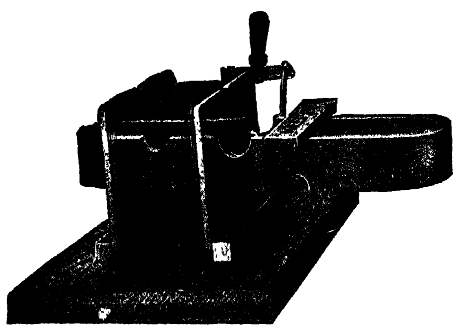


FIG. 7c.—Removing the Magnet.

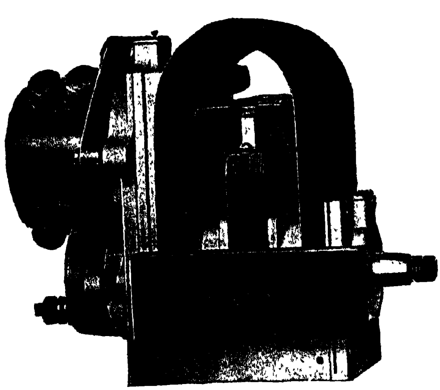


FIG. 7d.—Assembling the Magnets.

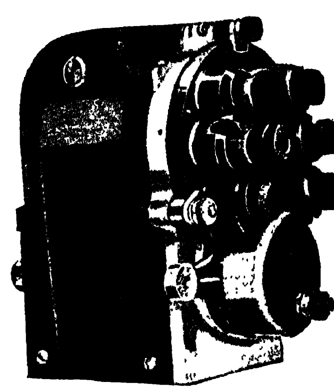


FIG. 7e.—Dixie Magneto for Six-cylinder Engines.

be needed. The repair work is divided into two classes: (1) those jobs that a general repairman may be expected to do, and (2) those that should be sent to a service station. Fully 95 per cent of magneto trouble is caused by excessive oil, carbon dust, dirt on different parts of the magneto, improper adjustment of the interrupter points, or weak magnets.

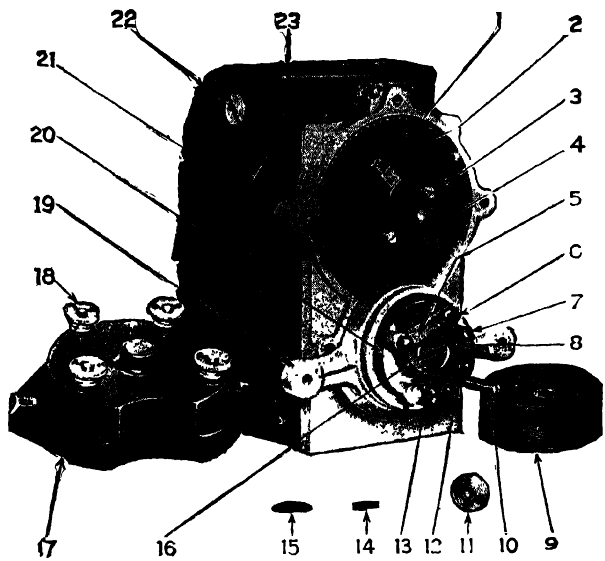


FIG. 7*f*.—Magneto Parts.

FRONT VIEW

Correct names of magneto parts

Distributo gear	13 Cam screw.
Distribut brush	14 Lock washer for ground stud nut.
Distribut finger screw.	15 Washer for ground stud
Distribut finger	16 Cam
Finger s ng for breaker bar	17. Distributor block
Breaker r	18 Thumb nut for distributor block.
Lock scr for platinum contact screw.	19 Breaker base
Platinun ontact screw	20 Breaker-bar spring
Breaker ver	21 Side plate
Ground st ud	22 Side-plate stud.
Thumb n t for ground stud	23 Magnet cover
Contact rew bracket	

Remagnetizing.—When magnets have been removed they should be remagnetized, if possible, before being placed on the magneto. Magnets should be remagnetized by means of a remagnetizer, usually consisting of a strong electromagnet or coil. Figure 7*a* shows a magnet-charging apparatus which can be used for this purpose. In this type

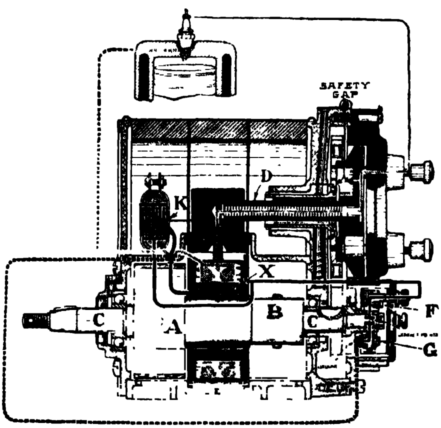
of remagnetizer a master magnet should be kept in the magnetizing coils.

When a magneto has been taken down and the magnets are to be recharged, attach the magnet to be magnetized to the master magnet in the coils, push it forward so that it is within the coils, and close the switch, permitting the current to flow for a few seconds. (Fig. 7b.)

Open the switch, pull the magnet forward, and attach the keeper across the side of the magnet having no half holes in it. (Fig. 7c.) Pull the magnets apart and place the magnet on the magneto with the keeper across the poles. (Fig. 7d.) When the magnet is in place, pull the keeper off; do not slide it off. It is not absolutely necessary to use keepers when removing or replacing the magnets, but from 6 to 10 per cent more efficiency may be retained by carrying out these instructions.

Figure 7e shows a Dixie magneto used on six-cylinder cars. In Fig. 7f the same magneto is shown with the parts named.

Another type of magneto, the K. W., is shown in Fig. 7g. This type is used on a four-cylinder truck or tractor.



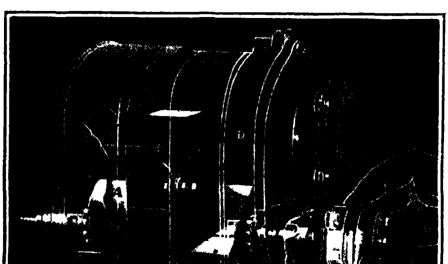


FIG. 7g.—Sectional and Phantom Views of K-W Magneto.

Figures 7h, 7i, 7j, and 7k show the Bosch magneto with sectional views and circuit diagrams. The above illustrations are typical of the types of modern magnetos.

While the principles of operation of these different types are the same, the construction varies in several details.

It is possible for any careful repairman to take a magneto apart, provided he examines the two gears on the armature and distributor shaft and makes sure that timing marks are on each and checks their line-up.

It rarely happens that a magneto is sent out with the gears not marked.

It is a wrong assembly of these gears that throws a magneto out of time. If no marks are found, make a mark on the two gears, using a sharp center punch or file, so that the same teeth may be meshed together when reassembling.

The repairman should first make a very careful examination of the parts necessary to remove to gain access to the gears on the magneto. After having satisfied himself that he can replace the gears as marked, he should proceed to take the rest of the magneto down. Parts should not be forced off. Use the fingers to take off the parts, and if they seem hard to remove make a very close examination to determine whether the part is screwed on or whether a wire would be broken if not loosened before the part is removed.

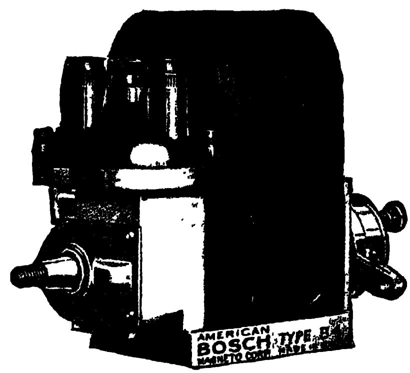


FIG. 7*h*.—Bosch Magneto.

After the magneto is down, clean all parts with a cloth moistened with kerosene. Wash in kerosene all the metal parts that have no windings fastened to them.

Now replace the parts as taken off and mesh the gears as marked. Recharge the magnets on a magnet charger as in Figs. 7*a*, 7*b*, and 7*c*. After replacing the magnets adjust the interrupter points according to instructions in the magneto repair book. Use a special magneto wrench for this purpose. Repair work such as replacing a condenser or new windings should be done only by an electrical expert since it requires special tools and considerable experience and skill to do the job. This second class of work vary rarely gives trouble, and therefore if instructions have been followed but little expert service work becomes necessary.

Before removing the magneto from the car, mark the couplings on the magneto and engine shaft; also look at the distributor brush and note its position. When replacing the magneto, turn the magneto shaft until the distributor brush is in the same position as before and see that the marks on the couplings line up.

With the couplings fastened together, check the magneto alignment. To do this, turn the crank shaft slowly and adjust until the magneto does not "wobble." Now fasten the cap screws in the base of the mag-

neto or the metal band over the magneto, according to the method of installation.

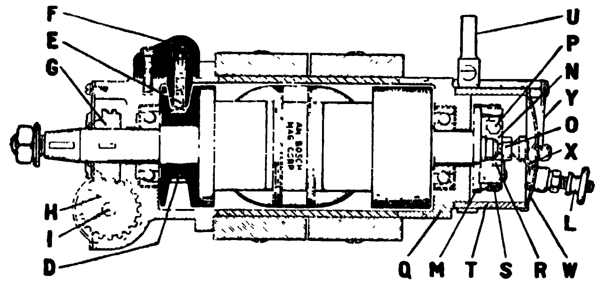


Fig. 7i.—Horizontal Section of Bosch Magneto.

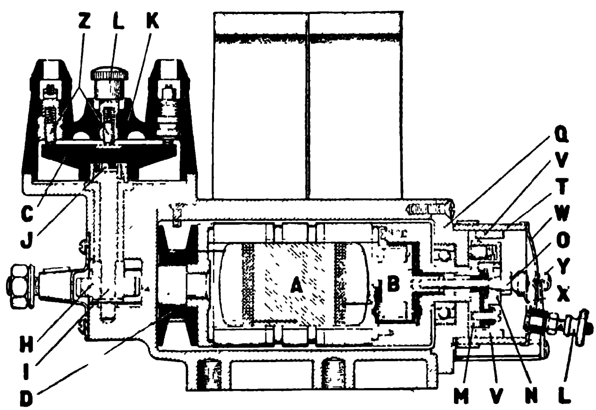


Fig. 7j.—Vertical Section of Bosch Magneto

A Armature
B Condenser
C Distributor rotor
D. Collector ring
E Collector brush.
F. Collect brush-holder.
G. Armatu e gear
H. Distrib or gear
I. Distrib or rotor shaft
J. Shaft a apter head
K. Distributor block
L. Terminal nut
M. Interrupter disk
N Contact block
O Interrupter fastening screw
P Contact screw—long
Q Rear end-plate
R Interrupter lever
S Interrupter operating spring
T Interrupter housing
U Interrupter housing control arm
V Interrupter cam
W End cap
X End cap contact spring with bru
Y Holding post spring
Z Distributor brush

To time a magneto, turn the crank until No. 1 piston is brought to top dead center on compression stroke. (See Job No. 3.) Magneto

points should be about to separate, with spark at full retard and distributor brush in contact with segment connected to No. 1 spark plug.

Figure 7*l* shows the coils and magnets of a Model T Ford magneto. Model A Ford Cars do not use this type of ignition. About the only troubles experienced with the Model T type are "shorted," "grounded," or burned-out coils and weak magnets. The magneto is extremely simple in construction and contains but one rotating part—the magnets, which are bolted to the flywheel. The clearance between the coils and the magnets should be about 0.030 inch to secure best results. Check crank shaft for end play as this will alter the air gap.

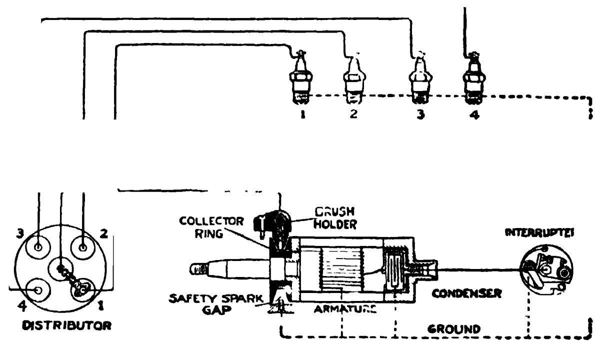


Fig. 7*k*.—Circuit Diagram Bosch Magneto.

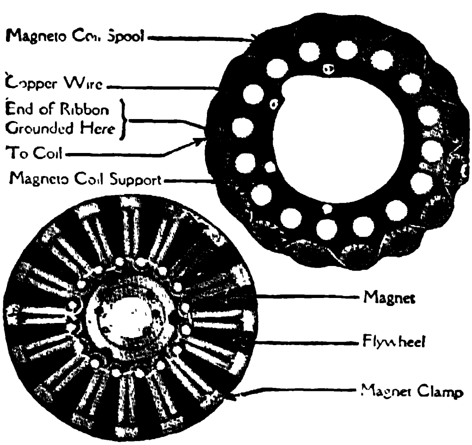


Fig. 7*l*.—Ford Magneto on Model T Car.

It is important always to mark the magnets before removing them and to replace them according to the way they were taken off.

If the distributor wires of a magneto are removed, they should be marked also so that they may be replaced as taken off.

It is not always necessary to remove the distributor when removing magnetos. As a rule the magneto may be removed by loosening the holding clamps and leaving the distributor wires connected.

Questions.

1. What are the usual troubles found in a magneto?
2. What is the first thing to do before removing a magneto from the car?

3. What must be done before the timing gears are disengaged from each other?
4. In case the gears are not marked, what should you do?
5. What "throws" a magneto out of time?
6. In removing any part of a magneto, what must always be done?
7. How will you know the correct adjustment for the interrupter points?
8. What kind of a wrench will be needed for the adjustment?
9. Should the general auto repairman replace a new condenser, interior windings, or a collector spool, or should this job go to a service station?
10. What must be done to magnets before they are removed from the base?
11. In resetting a magneto what precautions must be taken?
12. How may a magneto shaft be tested for alignment with the engine shaft?
13. How may you determine if a magneto is giving trouble?
14. Will it be necessary to remove the distributor wires from the distributor in all repair jobs on magnetos?
15. When it is necessary to remove the distributor wires, what precautions must be taken?

Job No. 8

REPAIRING MAGNETO SWITCH

References.—Part Two, pp. 456-60.

Operations Necessary to Perform the Job.

1. Test for trouble by removing switch wire from magneto; if "short" or loose connection is found, repair or replace parts.

Name of Materials, Parts, and Operations to be Reviewed before Performing the Job.

Materials.—Low-tension wire, rubber tape, solder, and paste.

Parts.—Switch blade, terminals, face plate, insulation and fastening screws, switch key.

Operations.—Testing for "short," "loose" connection, or "open" circuit.

Description of Operations.

Refer to Fig. 8*a* for the place on the magneto to which the switch wire is attached. All high-tension magnetos have a terminal on the magneto provided for this wire.

Since the high-tension current is generated only on the interruption of the primary circuit, it is evident that in order to cut out the ignition it is necessary merely to divert the primary current to a path which is not affected by the action of the magneto interrupter. This is accomplished as follows:

An insulated grounding terminal is provided on the end cap, with its inner end consisting of a spring with a carbon contact pressing against the head of the interrupter fastening screw. The outer end of the grounding terminal is connected by a low-tension cable to one side of the switch, and the other side of the switch is grounded by connecting another cable between it and the engine or frame.

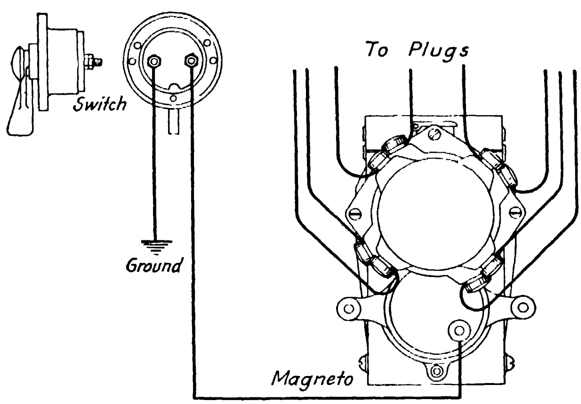


FIG. 8a.—Magneto and Ground Switch Connections.

When the magneto switch is open the primary current follows its normal path across the platinum interrupter contacts and is interrupted at each separation of these contacts; however, when the switch is closed, the primary current follows the path of least resistance and passes from the head of the interrupted fastening screw to the carbon contact of the grounding terminal, thence through the switch to the engine or frame and back to the magneto, and as the primary current remains uninterrupted when following this path, no ignition current is produced.

The switch may be tested for trouble as follows: Remove the switch wire from the magneto. If the engine will not start, the trouble in all probability is not in the switch since the switch must be open on high-tension magnetos when in operation. If the engine will start when the wire is removed and the switch is on "on" position, the switch will probably be found to be defective.

Disassemble the switch and make the necessary repairs. These usually consist of tightening the connections or replacing new parts.

Questions.

1. What is the function of a switch?
2. Are all high-tension magnetos provided with a switch terminal?

3. Describe a method for testing a switch.
4. How may a switch be repaired?
5. What advantages has a high-tension magneto over a battery system for a truck?
6. How many wires are required for the operation of a four-cylinder engine with a high-tension magneto?
7. What is the additional wire used for?
8. What is a simple method of determining whether a high-tension magneto is in good order and can deliver a spark which will start the engine?
9. If this test shows no spark, what should be done with the switch wire?
10. What attention should the distributor of a magneto receive?
11. What is the purpose of the so-called "safety gap"?
12. Why do we advance the spark lever to start an engine on the magneto and not on a battery system?

Job No. 9

CLEANING BATTERY TERMINALS

References.—Part Two, p. 436.

Operations Necessary to Perform the Job.

1. Disconnect battery terminals.
2. Clean terminals.
3. Replace terminals on battery.

Names of Parts and Operations Necessary to Perform the Job.

Parts.—Battery box, battery jars, positive and negative plates, separators, electrolyte, sealing compound, cover, vent caps, coil connections and terminals, filler caps, terminal posts, connector strip.

Operations.—"Cleaning terminals."

Description of Operations.

Figure 10*c* shows the wire terminals fastened to the battery posts. A corrosion often forms on the battery post which prevents the battery current from getting through the circuit. When terminals at battery are loose or corroded and starter button is pressed while lights are burning, the lights will go out and the starter will not operate, although battery is in good condition.

If a battery which will not furnish sufficient current to operate the starter or burn lights shows a full reading with the hydrometer and there

are no loose connecting straps, the battery terminals may be corroded. To repair, remove the caps and wires from the battery, mix baking soda and water to the consistency of cream, and apply the mixture to the posts to which the battery wires were fastened. After leaving the soda on for about fifteen minutes, remove it and rub the terminals with a stiff wire brush, after which a thin coating of vaseline should be applied and the wires replaced.

Ammonia can be used to clean battery posts and covers.

Questions.

1. What trouble may result if the battery terminals are corroded?
2. How may you determine when the battery terminals are corroded?
3. Describe a method for removing the corrosion.
4. How should the posts be treated after the corrosion is removed?
5. What is the last thing to do after the corrosion is removed and the posts treated?
6. What instrument is used to test a storage battery?
7. What will be the result of a loose mounting of a battery in the battery box?
8. If there is no spark on a battery ignition system, and a test indicates that there is not any current, how could the lights be used as a test of the battery?
9. If the lights will not burn when the switch is "on," what trouble may be located in the battery?

Job No. 10

CHARGING A STORAGE BATTERY

References.—Part Two, p. 437.

Operations Necessary to Perform the Job.

1. Remove battery from car.
2. Test battery with hydrometer for degree of charge.
3. Fill cells with distilled water.
4. Connect terminals to service wires of charging station.
5. Adjust rheostat for correct charging current.
6. Check battery temperature periodically.
7. Test battery with hydrometer and voltmeter for full charge.
8. Replace battery in car.
9. Inspect battery to see that it is correctly connected to generator.
10. If battery is in bad condition and does not hold charge, send to service station.

Names of Material, Tools, Operations, and Care of Equipment to be Reviewed before Performing the Job.

Material.—Distilled water.

Tools.—Hydrometer, voltmeter.

Operations.—"Charging battery," "testing charge," "checking temperature."

Care of Equipment.—Avoid spilling acid; wash off top of battery with ammonia or soda solution after charging; be careful not to "short" battery terminals; clean terminals thoroughly, replace battery in car with correct connections and fasten down to carrier.

Description of Operations.

The storage battery is an exceedingly important part of the equipment of the modern automobile. It is the " heart " of the electrical system, supplying the power for starting the engine and lighting the lamps, and often current for ignition as well.

The average car owner or operator is fairly familiar with the engine and its care, but is apt to regard the battery as mysterious and therefore to ignore it.

A storage battery, like the tires, will eventually wear out with use. The normal life, however can be very much shortened by neglect, the result of which is the same as that of abuse.

The function of the storage battery is to absorb and store up the electrical energy from the generator so that it can be used for starting, lighting, and ignition. It is important that the storage battery be kept securely fastened in its compartment, and it should be carefully wiped off at regular intervals to prevent the collection of dirt or foreign material which might short-circuit the battery and cause leakage of current. The terminals should be well coated with grease or vaseline to prevent corrosion.

Every two weeks, or in hot weather every week, the vent plugs should be removed and the battery filled with distilled water to a level $\frac{1}{4}$ inch above the plates. Each cell should be filled separately. If distilled water is not available, clean rain water or melted artificial ice may be used, but under no circumstances should hard water be put into the battery. *Do not under any circumstances add acid to the battery.*

The condition of the battery can best be tested by a hydrometer, which is an instrument for determining the specific gravity or density of the solution. The hydrometer indicates the extent to which the battery is charged. A convenient form of hydrometer (Fig. 10*a*) is enclosed in a glass syringe, with a rubber bulb. These may be pur-

chased from any dealer in automobile accessories. With the vent plug removed, enough electrolyte to float the hydrometer should be drawn

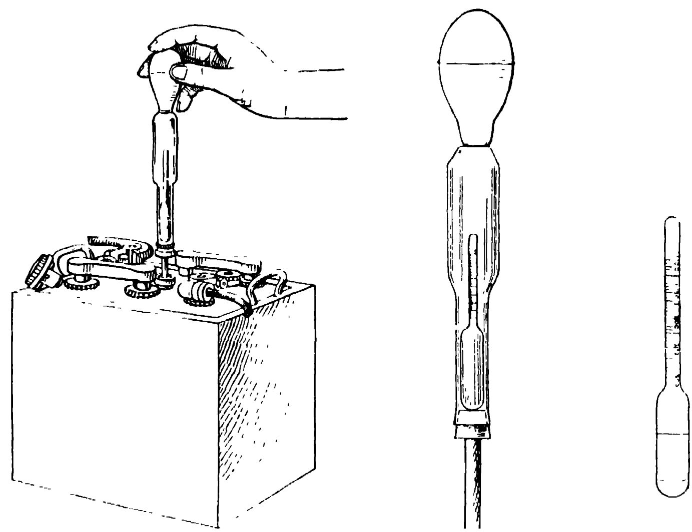


FIG. 10*a*.—Using a Hydrometer to Test the Specific Gravity of a Battery.

into the hydrometer syringe and a reading taken (Fig. 10*b*). The electrolyte should be tested separately for each cell. When the battery is fully charged, the electrolyte will test between 1275 and 1300. When the gravity is above 1200 it is more than half charged, and when between 1200 and 1150 less than half charged. In this event the lamps should be used sparingly until the gravity is restored to at least 1250. If the gravity is less than 1150, the battery is completely discharged and should be given a full charge at once from an outside source. There should not be a variation of over 25 points between the different cells. If the battery refuses to come to a full charge, the trouble is probably due to a reduced output from the generator, to defective cells, or to leakage around the wiring or around the battery terminals. The system should be examined carefully, and if necessary gone over by a competent *battery service man*.

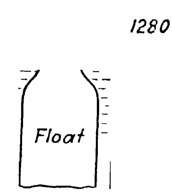


FIG. 10*b*.—Hydrometer Reading.

If one cell regularly requires more water than the others, a leaky jar is indicated and it should be replaced at once. If there is no leak

and the gravity of one cell remains persistently 50 or 75 points below the others, a partial short circuit within the cell or some other trouble is indicated, and the battery should be gone over by a competent service-station repairman. Acid or new electrolyte should never be put into a cell except by an experienced battery man. Low gravity in any one cell is a symptom of trouble which should be corrected, and the addition of acid will do no good, and may do positive harm.

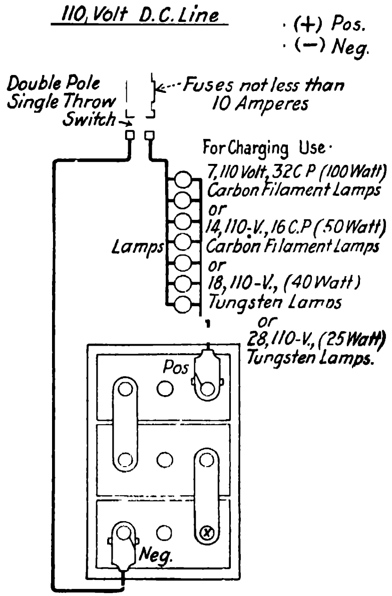


Fig. 10c.—Charging Circuit Diagram.

The charging rate of 6-volt and 12-volt batteries varies with their capacities. Use a current of. from 3 to 6 amperes where the rating is unknown. (Fig. 10c shows how to connect up a battery in a charging position.)

Continue the charge until the gravity has risen to a maximum, that is, until it shows no further rise over a period of five hours or six successive hourly hydrometer readings taken on the same cell.

The battery voltage should likewise rise to a maximum.

The vent plugs must be removed when the battery is being charged. Replace the vent plugs before installing the battery in the car.

If the battery becomes very warm during the charge (temperature of electrolyte above 110° F.) either stop the charge or reduce the rate until the temperature lowers.

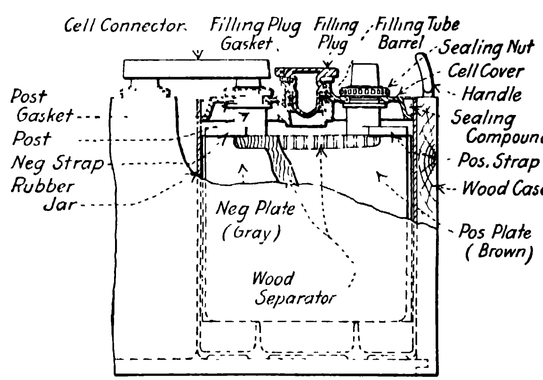


Fig. 10d.—Section of a Storage Battery.

A storage battery must be charged with a direct current; never use alternating current for the purpose as it will ruin the battery.

If alternating current only is available, it will be necessary to provide apparatus for converting it into direct current. Several forms of apparatus are on the market for this purpose. (See Figs. 10*e*, 10*f*, and 10*g*.)

Full directions for use accompany each type of charging equipment. Great care must be taken to protect the battery from an excessive charging rate and from being connected up in the reverse position. When the battery leads are reversed the battery not only does not receive a charge, but that which it had is soon lost through the reversed current.

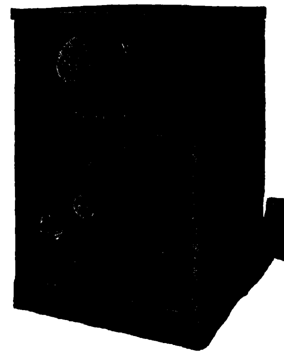


FIG. 10*e*.—Full-wave Charger.

If left in this position for a sufficient time, the polarity of the plates will become reversed. Figure 10*h* shows a charging circuit for four batteries, and Fig. 10*i* shows how to connect up a larger number of batteries as well as batteries of different capacities.

Since the charging current is opposing the pressure of the battery, its voltage must always exceed the voltage of all the cells or batteries

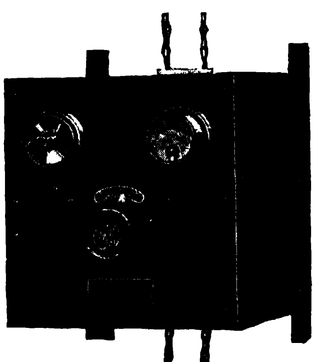


FIG. 10*f*.—6-ampere, 75-volt Tungar Battery Charger.

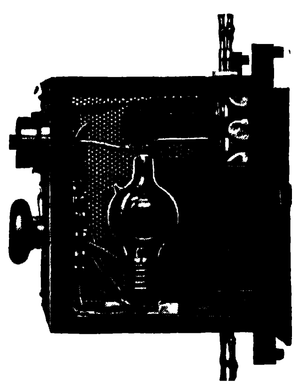


FIG. 10*g*.—Interior View of 6-ampere 75-volt Tungar Charger.

combined. Where a 75-volt charging rate is used, if ten 6-volt batteries, as shown in No. 2, Fig. 10*i*, are in the charging circuit, the total battery voltage opposing the charging voltage will be 60 volts. This is about the maximum which should be used in order that the desired charging rate of 3 to 6 amperes may be maintained.

Where more batteries are to be charged, a multiple or parallel set-up must be made, as in No. 1, Fig. 10*i*. When batteries of large capacity are brought in, they may be connected in circuit with batteries of smaller capacity, as shown in No. 3, Fig. 10*i*. A battery of 12 amperes charging capacity can be charged along with 6 ampere capacity batteries, but it will require twice the time for the 12-ampere battery to become fully charged. Never try to charge a 6-ampere battery at a 12-ampere rate.

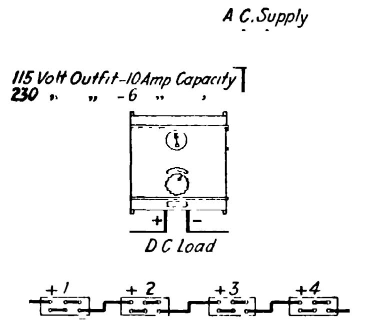


FIG. 10*h*.—Connections for Batteries and Battery Charger on *A–C* Service.

Always connect the positive terminal of the battery to the positive wire of the charging circuit and the negative battery terminal to the negative wire of the circuit.

To determine the polarity of the charging circuit, if a suitable voltmeter is not at hand, dip the ends of the two wires into a glass of water in which a teaspoonful of salt has been dissolved, care being taken to keep the wires at least an inch apart. When the current is turned on,

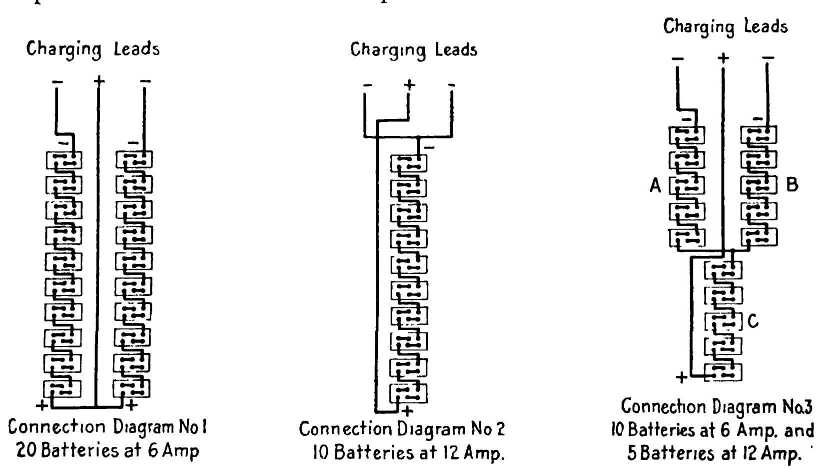


FIG. 10*i*.—Connection Diagram for Charging More than One Battery at a Time.

fine bubbles of gas will be given off from the negative wire. A very small number of larger bubbles will rise from the positive lead.

When the battery is to be charged from a 110-volt direct-current circuit, resistance must be used in series with the battery to reduce the

charging current of the circuit to the capacity of the battery. The most convenient resistances to use are 110-volt, 32-candle-power carbon filament lamps connected in parallel with each other, and the combination in series with the battery (Fig. 10c). With this arrangement, each lamp will allow approximately 1 ampere of charging current to pass through the battery. Therefore, the number of lamps required to charge the ordinary battery will be six.

If 32-candle-power lamps are not available, double the number of 16-candle-power lamps will be required. A slower charging rate will require a longer period of time to charge the battery.

If tungsten or other high-efficiency lamps are used, more will be required than if carbon-filament lamps are used, owing to the lower current rating of the former.

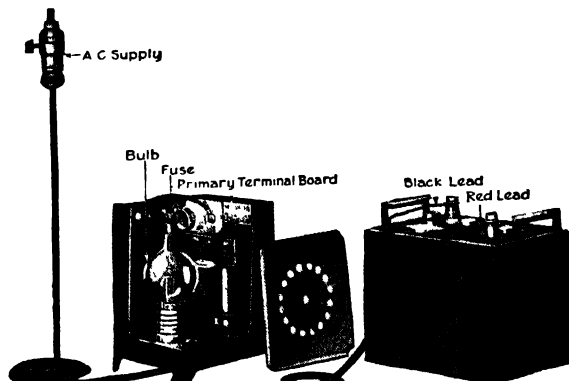


FIG. 10j.—Rectifier for Home Garage. (Tungar.)

If the battery is to be charged from a 220-volt circuit, use two lamps in series in place of each of the lamps necessary when charging from 110 volts.

If only a 500-volt to 600-volt circuit is available, it is necessary to use five lamps in series in place of each of the lamps when charging from 110 volts. (A 500-volt current is very dangerous and great care should be taken when using a circuit of this voltage.) A rheostat or some form of variable resistance makes a more compact and a very good current control.

Put on the charge at the proper current rate, as described, and continue the charge until the specific gravity of the electrolyte in all cells, as shown by the hydrometer syringe, has held at a maximum (ceased to rise) for a period of five or six hours and all the cells are gassing freely. When fully charged, place the battery where it will be dry, cool, and free from dust.

If the battery does not hold a charge under these conditions, it should be sent to a battery service station to be treated under successive charges or taken down and rebuilt.

Do not attempt to open up a battery, as it requires special tools. After the battery is charged, clean the top of the battery with ammonia or a solution of baking soda and water, being careful not to allow any of it to run into the cells. If the battery terminals are corroded, clean them and replace the battery in the car.

If in doubt as to the proper installation of the battery, turn on the lights and note whether the ammeter reads charge or discharge. If it shows charge, the battery is wrongly connected.

Always fasten the hold-down clamps to the battery if they are provided on the car. Batteries must be clamped in place to avoid breaking of jars.

If after replacing the battery you find the bottom of the battery box is wet, inspect the cells for the level of the water. If the level of one is lower than that of the other, the battery has a broken jar and should be sent to a service station.

Never pour water in the cells in cold weather unless the car is going to be used immediately, since the water will not mix with the acid and may freeze.

Do not allow acid to spill on your clothes or on the car. Sulphuric acid destroys clothing and metal parts (except lead) and is injurious to the skin.

Do not allow tools to come in contact with the cell connectors as they may "short-circuit" the battery.

The storage battery, besides serving as a source of current when the generator is not in operation, also plays an essential part on the regulation of the generator output. For this reason, if the battery is ever disconnected from the circuit, the generator must not be run unless it has first been grounded or rendered electrically inoperative by removing the field fuse. In order to run the engine under such conditions, it will, of course, be necessary to provide a temporary source of ignition current such as a set of dry cells, and the generator must be grounded.

Questions.

1. Where is the battery usually located?
2. What must be done before removing the battery wires?
3. Why is it necessary to test a battery with a hydrometer before placing it on charge?
4. Why should the cells be filled with distilled water before charging?
5. How may the positive and negative posts be distinguished from each other?
6. How must the battery wires be connected to the charging wires?
7. What determines the charging rate?

8. How long does it take to charge a battery?
9. If the battery will not hold a charge, what must be done with it?
10. What will the hydrometer read when the battery is fully charged?
11. What should be done to the battery after it is fully charged?
12. How may you determine when a battery is replaced in the car in the correct position?
13. How may you determine when the battery needs recharging?
14. How may you determine when the battery has a broken jar?
15. Why should the battery be securely fastened in the car?
16. Why should you avoid pouring water into a cell in cold weather unless the car is going to be used at once?
17. What precaution must be taken about handling tools around the battery?
18. Should a metal funnel be used when adding water or electrolyte?
19. What will be the effect of adding too much water?
20. What effect will acid have upon the wooden battery box?
21. What effect will it have upon surrounding metals?
22. If acid has been spilled, what parts may be affected by it?
23. What is recommended by the manufacturer for dampening the cloth with which the top of the battery is cleaned?
24. What will be the effect if the cloth is too wet and some of the cleaning liquid gets into the cells?
25. What will be the result if the acid soaks up into the terminals where the wires are attached?
26. What color will the terminals show?
27. What effect will this have on the electrical contact?
28. What can be applied to the terminals to prevent this corrosive action?

Job No. 11

EMERGENCY REPAIRS TO BATTERY TERMINALS

References.—Part Two, p. 436.

Operations Necessary to Perform the Job.

1. If terminal parts are broken off, drill out posts.
2. Clean surface.
3. Reweld.

Description of Operations.

To repair a broken battery terminal, drill through the cell connector at (x), (Fig. 10*c*), with a $\frac{5}{8}$-inch drill, clean the cell connectors and battery post with a knife or wire brush. The vent plugs should now be

removed so as to prevent danger from a gas explosion. Clean all parts thoroughly and reweld terminal, using an acetylene and air torch, an illuminating gas and air torch, or an acetylene torch. If a torch is not available, heat a soldering iron, soften the post of the cell connector, and allow the melted lead to run into the drilled hole, in the cell connector, flush with its top surface.

If the post is broken off below the sealing compound, the battery must be opened and the post built up. This requires special tools and is the work of a battery-service man.

A broken post is usually due to dirt remaining on the post when it was built up. This dirt forms a seam in the post and causes it to break when the battery receives a sudden jar.

Questions.

1. What tests should be made for a broken terminal?
2. How should the terminals be cleaned?
3. What causes terminals to break?
4. Why is it necessary to remove all vent caps when rewelding a post?
5. Why must the lead be heated on both battery posts and cell connectors before allowing the melted lead to run into the drilled hole?
6. When will it be impossible to repair a broken connection by the method described?
7. Under what conditions should a battery be sent to a service station?
8. If the terminals have once become badly corroded, what must be done to them before anything is applied to protect them from further action of the acid?
9. If the nut is difficult to remove, what precaution should be taken to prevent injury to the terminal or to the top of the battery box?
10. If a battery is not properly anchored, what will be the effect of the vibration?

Job No. 12

REPLACING CABLE TERMINALS

References.– Part Two, p. 436.

Operations Necessary to Perform the Job.

1. Remove old terminals.
2. Clean and tin end of cable and cable slot in terminal.
3. Sweat on new terminal.

Names of Materials, Tools, and Operations to be Reviewed before Performing the Job.

Materials.—Lead solder, paste.
Tools.—Blow torch, wire brush.
Operations.—"Sweating" terminals, "tinning."

Description of Operations.

The ends of the cables that fasten to the battery sometimes work loose from the terminal, and very frequently terminals must be replaced, owing to destruction by the action of acid.

To repair the connection, clean the wire, using a knife or a stiff wire brush, and clean out the hole in the terminal.

To tin the ends of the wire, twist the strands and solder them together, using a non-corrosive soldering paste. To attach the terminal, insert the end of the cable, heat the terminal, and allow the melted solder to run around the wires or to "sweat on." Now replace the connection on the battery post, after making an examination of the battery post for corrosion, and test the battery.

Questions.

1. How should a broken terminal wire be prepared for soldering?
2. How should the wire be sweated into the terminal?
3. What precaution should be taken before fastening the terminal to the battery post?

Job No. 13

TESTING BATTERY AND ADDING DISTILLED WATER

References.—Part Two, p. 437.

Operations Necessary to Perform the Job.

1. Remove vent plugs.
2. Test solution with hydrometer for strength.
3. Add water as necessary.

Names of Material, Tools, Operations, and Care of Equipment to be Reviewed before Performing the Job.

Material.—Distilled water.
Tools. Hydrometer.

Operations.—Reading or testing specific gravity of electrolyte.

Care of Equipment.—Do not use too much water. Keep tools and parts off top of battery. Guard against danger from freezing or damage to battery from not being used.

Safety First.—Danger to man if he attempts to make electrolyte by pouring water into acid.

Description of Operations.

Water must be added to the battery often enough to keep the plates covered. If the plates are exposed for any length of time, they may be seriously damaged and the battery pressure will be reduced.

The length of time a battery can go without the addition of water will depend upon the season of the year, water being required more frequently in summer than in winter.

The best plan is to make it an invariable rule to remove the filling plugs once each week and add water if the level of the electrolyte is below the bottom of the filling tube.

Never bring an open flame, such as a match or candle, near the battery.

Always add the water regularly, though the battery may seem to work all right without it.

In freezing weather, when necessary to add water, always do it just before running the car.

If the temperature is extremely low, start the engine so that the battery is charging before adding water.

The reason for this precaution is that water, being lighter than the electrolyte, will remain on the surface and will soon freeze in cold weather. If the engine is run, however, the gassing, due to the charging current, will thoroughly mix the water with the electrolyte. Also, the motion of the car when running will have a similar effect. Thoroughly mixed electrolyte will not freeze solid except at very low temperatures.

The electrolyte in a fully charged battery (gravity above 1280) freezes at about 60 degrees below zero Fahrenheit; while in a normally discharged battery (gravity 1150 to 1175) it freezes at about zero Fahrenheit. Therefore it is especially important to have the battery well charged when the car is standing in a very cold place.

To add water, remove the filling plugs by turning to the left, and, if the level of the electrolyte is found to be below the bottom of the filling tube, add water by means of the hydrometer syringe or a very small pitcher until the level begins to rise in the tube (Fig. 13*a*).

After adding water be sure to replace the filling plugs and tighten

them by turning to the right. If the filling plugs are not tightened, the electrolyte will splash out of the battery and cause damage.

After filling the cells, wipe off the top of the battery. The water used must be of reasonable purity, as the use of impure water will injure the plates. Distilled water, melted artificial ice, or rain water collected in clean receptacles is recommended. Never use spring or well water.

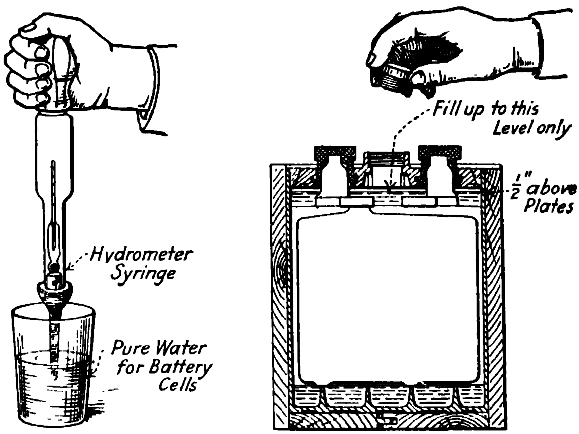


Fig. 13a.—Filling the Battery with Distilled Water.

Nothing but water should be put into the cells. If acid of any kind, alcohol, or in fact anything but water is added to the cells, it will result in very serious injury to the plates and may ruin them.

The electrolyte in a cell consists of a mixture of sulphuric acid and water. Sulphuric acid does not evaporate; water does. When the level of the electrolyte in a cell becomes low, it is due, under normal conditions, to the evaporation of water, which should be replaced with water only.

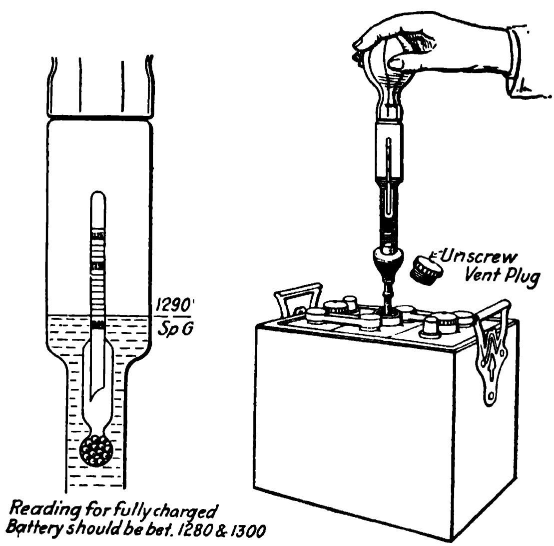


Fig. 13b.—Testing the Electrolyte.

There being no loss of acid, it is never necessary during normal service to add acid to a battery.

If the electrolyte has been spilled from the battery by accident, the loss may be replaced with electrolyte of the right specific gravity.

Questions.

1. What reading should a hydrometer show for a fully charged battery?
2. For a discharged battery?
3. When will it be necessary to add acid to the electrolyte?
4. Should the service man pour the acid in the water or the water in the acid when making up a solution of electrolyte? What difference does it make?
5. With what should the cells of a storage battery be refilled? What kind?
6. How often is this necessary?
7. Should the acid be renewed? Why?
8. How much water should be added?
9. Should the water for use in the battery be kept in metal containers?
10. Why is spring or well water unsuited for battery use?

Job No. 14

CLEANING COMMUTATOR AND BRUSHES ON MOTOR OR GENERATOR

References.—Part Two, pp. 450-2.

Operations Necessary to Perform the Job.

1. Remove cover plate.
2. Clean brushes and commutator with fine sandpaper.
3. Replace cover.

Names of Materials, Tools, Parts, and Operations to be Reviewed before Performing the Job.

Materials.—Sandpaper, cotton rags, kerosene.

Tools.—Wooden probe, long-nosed pliers, screw driver or small wrench.

Parts.—Brush cover, brushes, commutator, segments, mica, coil, fields, field terminals, brush springs, generator switch, relay, coupling, bearings, clutch, brush-holder.

Operations.—Cleaning commutator, cleaning brushes, fitting new brushes.

Care of Equipment.—Repairman must not use emery in place of sandpaper. Care must be taken to avoid making the surface of the commutator uneven through pressure on the sandpaper.

Description of Operations.

A removable dust-tight cover around the commutator end of most generators provides easy access to the commutator and brushes. Inspection twice in a season will forestall any tendency to score the commutator, such as dirt causing a poor brush contact. The commutator wears naturally to a brownish color in normal use, but if it appears black or scored the surface should be smoothed with a piece of fine (No. 00) sandpaper. Never use emery cloth for this purpose. Emery is a conductor and will short-circuit the commutator segments if lodged between them. (See Fig. 14*a*.)

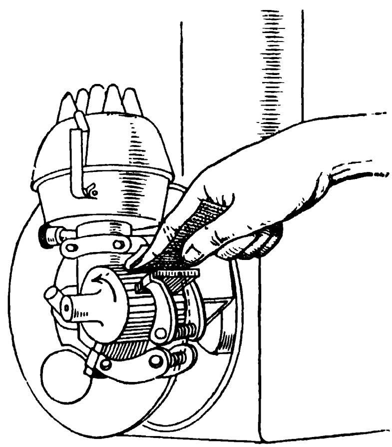


FIG. 14*a*.—Cleaning Commutator.

After smoothing down the commutator examine it carefully, and remove all particles of metal which may bridge across from one copper segment to another. Blow out every particle of carbon dust which may have accumulated in the generator case.

If the brushes need fitting, stop the generator or motor and place a long strip of sandpaper between the brush and the commutator (sand side against the brush). (See Figs. 14*b* and 14*c*.) Press lightly upon the brush with the fingers and withdraw the sandpaper. This causes the contact point of the brush to conform to the curved surface of the commutator.

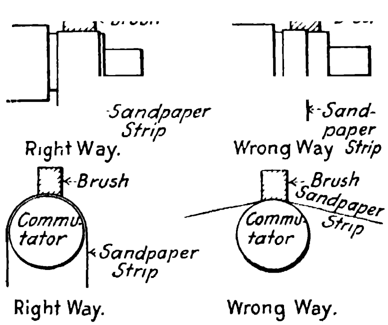


FIG. 14*b*.—Fitting Brushes.

See that there is just enough spring tension on the carbon brushes to insure good contact on the commutator. Too much tension will cause heating and unnecessary wear to brushes and commutator segments.

Make certain that the brushes are making even contact with the commutator. When the brushes become worn to such an extent as to need replacement, order new ones from the dealer or directly from the factory. Do not use cheap carbon brushes or substitutes.

Some generators are constructed with all brushes insulated, but the majority have one brush which is grounded. Two-brush starters, in the main, contain one insulated brush and one grounded brush. Two insulated and two grounded brushes are found in four-brush starters.

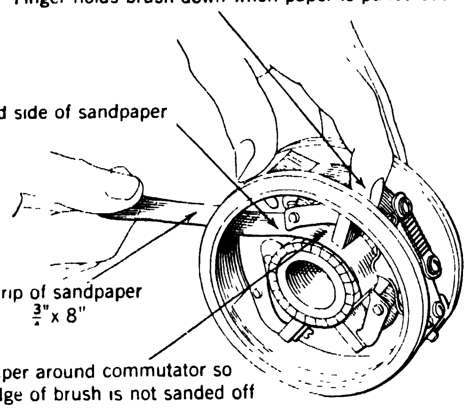


FIG. 14c.—Sanding Brushes.

After reassembling and replacing all parts, start the engine and test the generator for its charging rate, noting the reading of the ammeter. If it does not respond, so that at a normal speed the ammeter reading shows a charging current, a further inspection should be made and the brushes adjusted as noted in Job No. 15.

Questions.

1. In removing the cover plate on a motor or generator, should all screws that are on the end of the machine be removed?
2. If they should not, how may the repairman determine which should be left in the plate?
3. Why not use emery cloth instead of sandpaper when cleaning a commutator?
4. Should the mica that is between the commutator segments be higher or lower than the copper segments? Give reasons.
5. What causes the brushes to squeak, and how may the defect be overcome?
6. What precautions should be taken against "short-circuiting" the battery?
7. What will be the effect of having brushes on the generator that are not fitted to the commutator?
8. What is meant by "single-unit system" and "two-unit system" on starting and lighting equipment?
9. Of what material are starting motor brushes usually made? Generator brushes?
10. What causes "excessive heating" in the commutator and brushes?

Job No. 15

ADJUSTING GENERATOR CHARGE

References.—Part Two, pp. 450-2.

Operations Necessary to Perform the Job.

1. If generator brushes and commutator are clean and in good condition and the charging rate is not normal, locate the charging regulator.
2. Adjust the regulator for a normal charging current.
3. Check output with an accurate ammeter.

Names of Tools and Parts to be Reviewed before Performing the Job.

Tools.—Long-nosed pliers, screw-driver, third-brush wrench.

Parts.—The single-unit system incorporates the starter and generator in one unit. The two-unit system maintains the starter and generator independent of each other. Generator, brush, brush-holder, gear, shaft, coupling, armature, commutator, field, poles, coils, segments, regulating screw, thermostat.

Description of Operations.

Where the commutator and brushes are clean and the brushes are seating properly and still the charging rate is not normal, the repairman should adjust the generator to give the desired output. There are three common methods for making this adjustment.

(1) *Constant-current Regulation.* (Fig. 15*b*.)—This regulator controls the output of the generator by automatically cutting a resistance into the circuit of the shunt field. To increase the output of the generator using this type of control, tighten the tension on the spring (*a*). This increased tension makes it more difficult to break the points at (*c*) and thus keeps the additional resistance out of the shunt-field circuit. Where the repairman is not familiar with the regulation provided on an automobile, it is best to consult a manufacturer's instruction book.

(2) *The second, or voltage regulator* controls the output by controlling the voltage. This is also regulated by increasing and decreasing the resistance in the shunt field. The voltage regulator is constructed similar to the current regulator except that the coil winding is fine wire and the main current flows through a shunt from *M* to *N* (Fig. 15*b*). Where the repairman has to adjust a regulator of this type, he may increase the current by increasing the tension on spring (*a*).

(3) Another type of control is the *third-brush regulation* (Figs. 15*a* and 15*d*). This regulation increases or decreases the current by weakening or strengthening the magnetic field of the generator. Ordinarily the output of a generator increases with an increase in speed. Since motor cars operate at a widely varying speed, some method of regulation is necessary to prevent damage to the generator and battery at high speed. This is taken care of by a third-brush form of regulator which is exceedingly simple. A third brush to which one of the generator fields is connected is mounted on an adjustable plate between the two main brushes (Fig. 15*c*). When this brush is used in connection with the generator it is a natural function of the generator to have the field current decrease at higher speeds with a corresponding decrease in the generator output. With this form of regulation it is possible to obtain a fairly high charging rate at low speeds as well as a charging rate which is satisfactory for higher car speeds.

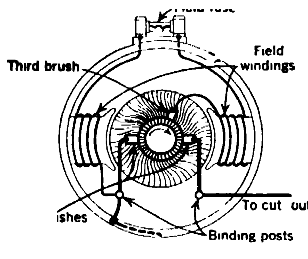


FIG. 15c.—Third-brush Generator. (Northeast.)

The charging rate can be changed if necessary by loosening the screws holding the third-brush plate, as shown in illustration, and shifting the brush in the direction of rotation of the armature to increase the charging rate and against the rotation to decrease the charging rate. In no case should the ammeter indicate a charging rate in excess of 14 amperes when the generator is hot. This rate is the maximum capacity of most generators, and higher rates will result in serious damage. Whenever the third brush is moved in either direction, it should be fitted to the commutator by sanding the brush with fine sandpaper between the brush and the commutator, with the sand side next to the brush. If this is not done the brush may fit the commutator imperfectly and the

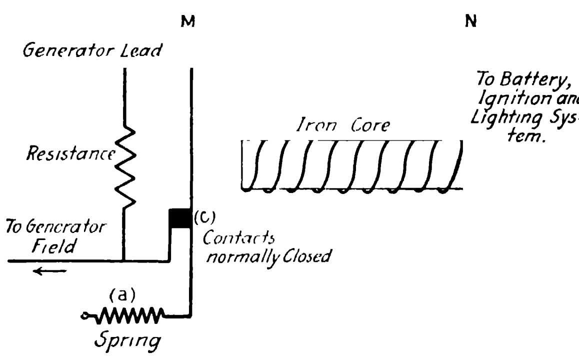


FIG. 15b.—Current Regulator.

charging rate will be lower than when the brush fits properly. This adjustment should not be made except by a competent mechanic, and then the ammeter on the instrument board should be carefully observed so that it will not show an excessive charging rate. Be sure after making this adjustment to tighten securely the screws of the third brush. The

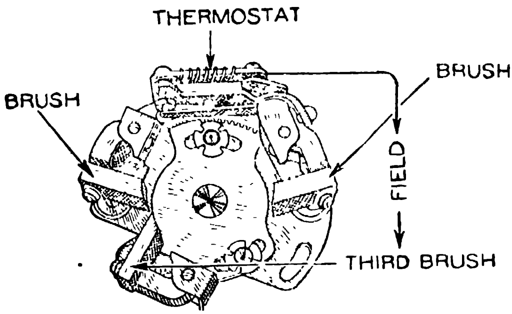


FIG. 15c.—Third-brush Adjustment.

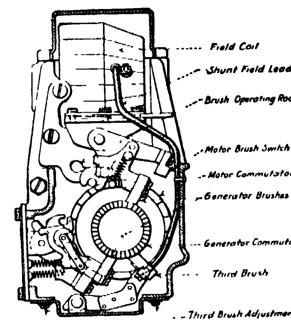


FIG. 15d.—Commutator End of Generator, Showing Third Brush.

generator should be lubricated once every week with four or five drops of high-grade engine oil at each of the oilers.

The thermostat resistance (shown in Figs. 15c and 15e) regulates the output of the generator with the increase and decrease in temperature. Heating and cooling of the resistance makes it brittle, and eventually

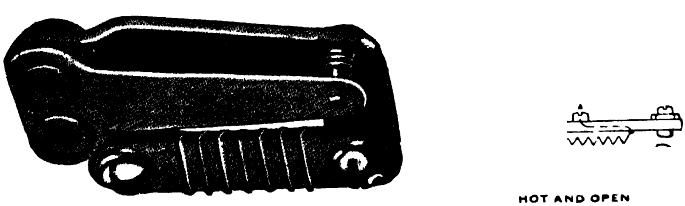


FIG. 15e.—Thermostat Control.

burns it out. The generator will charge when cool, but as soon as the points separate the field circuit is broken and no current is generated.

A new resistance unit should be installed before the generator charging circuit is connected again. If the generator circuit be connected again without installing a new resistance unit, the generator will pro-

duce a full charging current at the start, but after the car has been run long enough to cause the thermostat to open, the output will drop to zero, since the burned-out resistance cuts off the field current entirely. Under this condition the thermostat opens, and for that reason a new resistance unit should be installed promptly or else the contact points will be destroyed. The thermostat resistance is easily replaced.

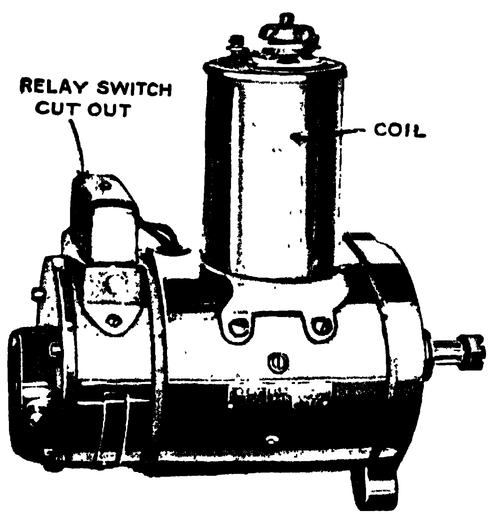


FIG. 15*f*.—Remy Generator.

The thermostat is substantially made to withstand the most excessive vibration without impairing its operation, but its accuracy would be destroyed by prying the contacts apart.

A larger-capacity generator could not safely be used without some means of protecting the battery from overheating, which a continuous high charge rate would cause. This is true especially in the summer time and results in serious consequent damage to the plates and a material shortening of the life of the battery.

The thermostat is composed of a resistance unit, two silver contact points, and a spring blade holding one of the contact points. The blade is made of a strip of spring brass welded to a strip of nickel steel, a combination which warps at its free end when heated, because of the greater expansion of the brass side. The blade is riveted to the bracket permanently, through insulating washers, and the spring tension is fixed so that it holds the two contacts firmly together at low temperatures. As soon as the temperature rises to approximately 175° F. the blade bends and separates the contacts.

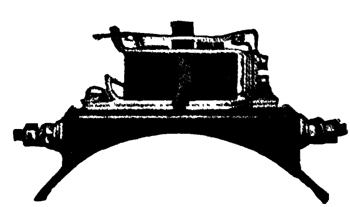


FIG. 15*g*.—Relay Switch Cutout.

When the thermostat contacts are closed a full field current passes through them and permits full current output from the generator. After the engine has been run for a sufficient time, tending to heat

up the battery, the automatic thermostat inserts the resistance into the field circuit, and thus reduces the output.

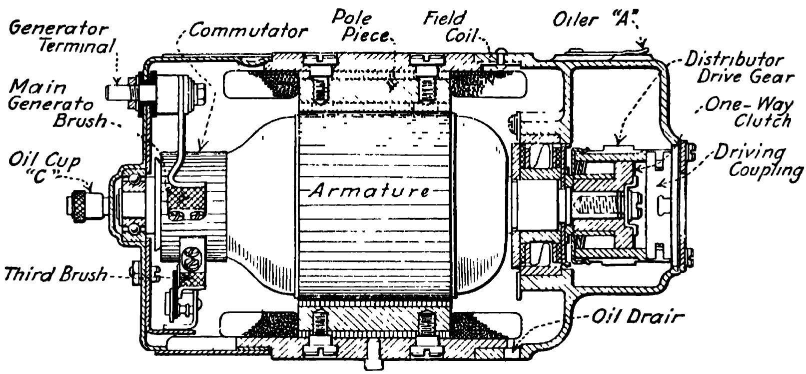


FIG. 15*h*.—Generator in Section. (Delco.)

Questions.

1. What is the quickest method to use in locating the charging regulator on a car with which you are not familiar?
2. At about what rate of car speed should you obtain a normal charging rate?
3. How would you determine the rate at which the generator should charge the battery?
4. State briefly how to adjust a voltage regulation, a current regulation, a third-brush regulation.
5. At what car speed does the average charging relay operate so as to cut in on the battery?
6. Which of the above methods of current control is used most?
7. What is the average amount of current used by each of the electrical devices on an automobile?
8. If the car shows a "charge" on the ammeter, in what direction is the current flowing through the battery?
9. If it shows "discharge," in what direction is the current flowing?

JOB No. 16

REPLACING FUSE

References.—Part Two, p. 442.

Operations Necessary to Perform the Job.

1. Locate fuse block.
2. Remove blown fuse.
3. Install new fuse and test circuits.

Names of Material and Parts to be Reviewed before Performing the Job.

Material.—New cartridge fuses.

Parts.—Junction box, junction-box screw, junction box cover, fuse box, fuse-box cover, fuse block, fuse clip, fuse, junction panel.

Description of Operations.

Usually the fuse block (Fig. 16*a*) is located on the dash just under the hood of the automobile or at the rear of the lighting switch. If it is not in either of these positions and cannot be easily located elsewhere, consult the manufacturer's wiring diagram. On some cars circuit-breakers are used in place of fuses to protect the wiring. The blown fuse will show white or smoky and should be removed with the fingers or a piece of wood so as to prevent "shorting" other fuses. In case of a short circuit the fuses protect the battery from discharging. When a short circuit occurs, an excessive current flows through the conductors or wires, melting or blowing the fuse to open the circuit. If all the lights fail to burn, look to see if the fuse is blown. Before replacing it with the extra one which is sometimes carried in the fuse block on the right side, look over the lighting wires to see that there is no "short circuit" or "ground."

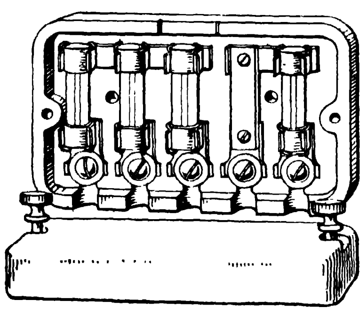


Fig. 16*a*.—Fuse Block.

In looking for "grounds" an abrasion of the insulation on the wire or a mechanical contact between the ends of the cable or current-carrying parts of the wiring devices and the metal of the car, sockets, shells, etc., should especially be looked for. When the trouble has been located and corrected, then replace the blown fuse with another of the same capacity.

If the trouble cannot be located immediately, leave out the fuse until the trouble has been located. If the trouble is found in a particular lamp socket, disconnect the attachment plug from this socket until the trouble can be corrected. Care should be taken to see that the removed plug does not touch the car frame.

If all the lights do not burn after a new fuse has been put in, there is an open circuit between the battery and the lights. Examine the connections at the battery, the connections on the starting switch, and the connections on the back of the dash switch. If all these connections are clean, tight, and making good electrical contact, look for a broken wire between these points. Dirty or burned switch contacts often cause

lighting troubles. Cleaning and bending of switch contacts will remedy the trouble.

If only one lamp does not burn, look for a loose connection, a broken wire, or a burned-out bulb in that circuit only.

FIG. 16b.—Fuses.

If a lamp goes out for an instant only, there is probably a loose connection on this socket; but if all the lamps act this way, there is a loose connection between the battery and the fuse block or in the fuse block.

Dim lights when the engine is idle indicate that the battery is getting low.

Instead of using fuses, a circuit-breaker is located on the back of the combination switch on some cars. (See Figs. 16c and 16d.) This is a protective device which takes the place of fuses. The normal current of the lighting circuit does not affect the circuit-breaker; but in the event of an abnormally heavy current, such as would be caused by a grounding of any one of the lighting circuits, the circuit-breaker automatically starts to vibrate. This causes the circuit-breaker to operate and intermittently to cut off the flow of current, thus causing a clicking sound. This will continue until the ground is removed, or until the switch is operated to cut off the circuit on which the ground exists. In this manner the circuit-breaker protects the wiring. As soon as the ground or short circuit is removed the circuit-breaker restores the circuit and there is nothing to replace, as in the case of a blown fuse. If all lights refuse to burn or a flickering of the lights is noted when driving over rough roads, the circuit-breaker is usually at fault. Clean the contacts or increase the spring tension to remedy this condition.

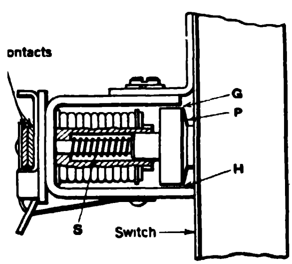


FIG. 16c.—Circuit-breaker Construction.

Questions.

1. Where is the fuse block generally located?
2. How may you locate a blown fuse?
3. Should a blown fuse be replaced by one of the same, of a higher, or of a lower ampere capacity?
4. What causes a fuse to blow out?
5. What is the purpose of a fuse in the lighting circuit?

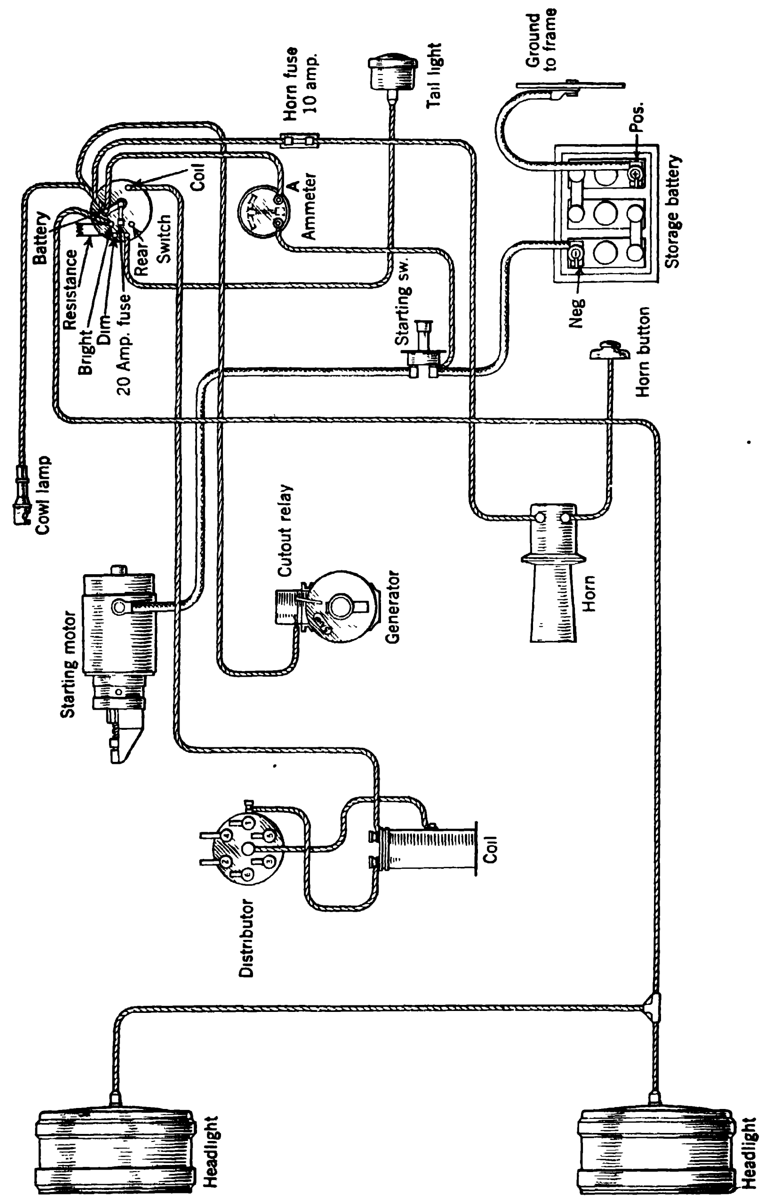


FIG. 16*d*.—Wiring Diagram. (Velie.)

6. What may be used as a substitute for a fuse for emergency repairs?
7. What other device besides a fuse is used to protect the circuit?
8. Where is it usually located?
9. How does it operate?
10. What are the advantages in its use?

Job No. 17

CLEANING, FOCUSING AND ADJUSTING LAMPS

Operations Necessary to Perform the Job.

1. Remove lamp doors.
2. Clean lens with clean waste.
3. Examine bulbs carefully.
4. Adjust lamp bulb for correct focus.
5. Adjust lamp brackets for correct horizontal and vertical position of light beam.
6. Replace lamp doors.

Names of Parts to be Reviewed before Performing the Job.

Parts. - Head lamp, tail lamp, side lamp, instrument lamp, dome lamp, pillar lamp, inspection lamp, inspection-lamp cord, inspection-lamp plug, inspection-lamp socket, head-lamp socket, head-lamp support, head-lamp support tie-rod, tail-lamp support, reflector, adjusting screw, lenses.

Description of Operations.

A commonly used and generally accepted method of adjusting head lights is carried out by projecting the head-light rays against a wall upon which specified limitations for the rays have been outlined. (See Figs. 17*a* and 17*b*.) The floor in front of the wall must be level to secure satisfactory results.

To make the adjustments, drive the car toward the wall squarely until the head lights are 25 feet from the surface on which the adjustment plan is to be drawn. Draw a vertical line on the wall to indicate the center of the car, and draw vertical lines at either side to indicate the centers of the head-light bulbs. Measure the distance from the floor to the center of the head-light bulbs and draw a horizontal line on the

wall at the same height. Draw a horizontal line 1 foot below the first horizontal line and parallel to it.

Remove the lamp doors and inspect the reflectors. The reflectors must be clean and bright to project the rays in a satisfactory manner. Old reflectors which are dented, bent, or rusty should be replaced. Dull or tarnished reflectors should be resilvered so as to restore them to their original appearance and efficiency. Slightly tarnished or spotted reflectors can be cleaned in several ways. A satisfactory method is to saturate a soft, clean piece of white cloth with alcohol, rub the reflector, and then polish it with soft, clean, dry cloth. In a similar manner, dry

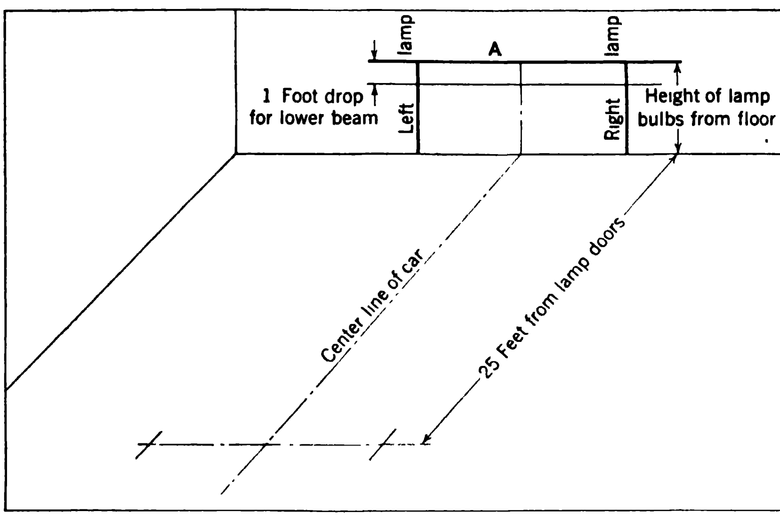


FIG. 17*a*.—Head-light Adjusting Space Plan.

rouge placed on a soft, clean chamois skin and saturated with alcohol is very effective as a cleaner. When applying the rouge draw the chamois from the center of the reflector toward the outer edges. Avoid a circular motion as this tends to destroy the reflector finish. Another piece of clean, soft chamois should be used to polish the reflector. Chamois skins used to clean reflectors should not be used for any other purpose. Brief exposures to unfavorable weather will ruin the finish of a reflector, and this usually happens when the lamp doors and lenses are broken and the reflectors are exposed to the weather.

Check the type, voltage, and candle power of the head-light bulbs. Any bulbs that are discolored or do not burn brilliantly should be replaced. If two-filament bulbs are employed, be sure they are inserted properly.

When making the adjustments turn the lighting switch to "bright" and cover one head light or render it inoperative while the other lamp

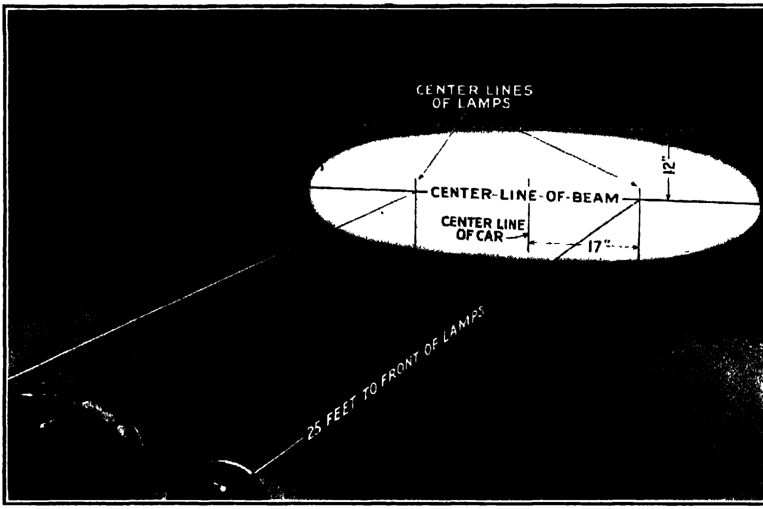


FIG. 17*b*.—Head Lamps Focused and Aligned.

is focused. Head lights are focused by moving the bulb and its socket to or from the reflector. This action is controlled by a screw, the head of which is exposed near the center of the lamp body (Fig. 17*d*). Turning the screw left or right moves the bulb toward or away from the

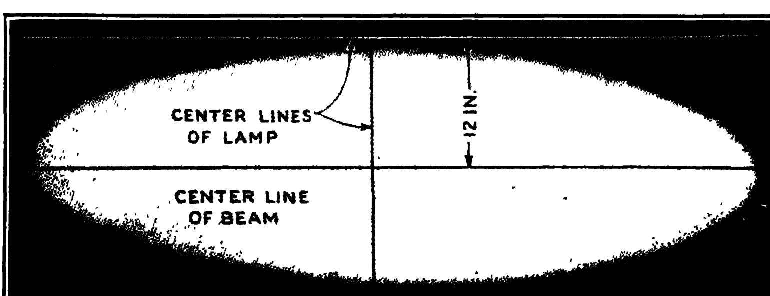


FIG. 17*c*.—Photographic Reproduction of the Focused Beam with Lens in Place. Screen 25 feet from lamp.

reflector. When adjusting move the bulb until an intensive ray is projected on the wall, free from black spots and black circles, and then proceed in the same manner to focus the second lamp while the first is covered.

Special non-glare reflectors are used on many cars. Plain, clear glass is usually employed for the lenses when non-glare reflectors are used. Non-glare reflectors control and spread the rays of light in the same manner as special non-glare lenses. When lights equipped with special reflectors are focused, the rays of light projected on the wall will not be circular in shape as they are when the regular-type reflector is used, but will assume an oval shape with the smaller dimension of the oval in the vertical.

As a precaution, when making these adjustments, place the normal passenger load in the car and proceed to adjust the lamps while the car is loaded. Care should be taken to see that the tires are not under-inflated, as this condition will tend to prevent an accurate setting of the

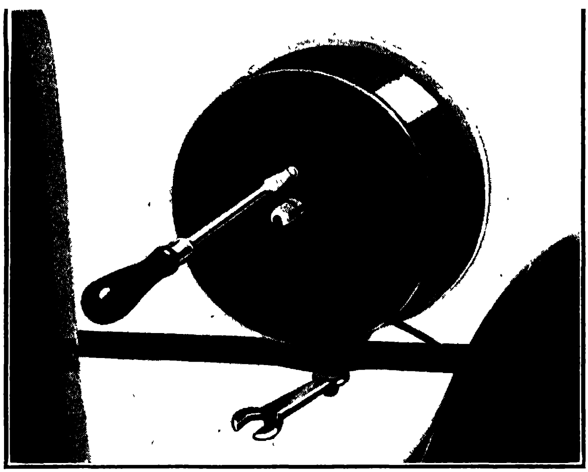


Fig. 17*d*.—Method of Adjusting Head Lamp.

lamps. Motor-vehicle bureaus and manufacturers issue bulletins specifying the amount of tilt necessary for a correct adjustment of the head lights when the vehicle contains no passenger load. Under these conditions the tilt of the lamp compensates for the rise of the rays when the car is loaded. In every case, the rays must not be higher than the uppermost horizontal line, and the center of the rays should fall at the intersection of the vertical line denoting the center of the head-light bulb and the horizontal line 1 foot below the uppermost horizontal line. If the rays are too high or too low, bend or adjust the brackets so as to project the rays at the proper point. The rays may extend to the right or to the left of the prescribed intersection; in this case it will be necessary to twist the head light to bring the rays to the proper point.

The repairman should now replace the head-light rims and lenses and check the adjustment of the right and left head lights individually. It is very essential that the packing between the lens and the reflector be replaced, because it acts as a seal and prevents dust and moisture from entering the lamp, thereby destroying the reflector finish.

Questions.

1. Why are head-lamp doors made dust and moisture proof?
2. How far should the car be from the wall when the lights are being adjusted?
3. What are the different mechanical devices placed on the lamp to adjust the focus?
4. What should be used in polishing a reflector?
5. Why should the reflector be rubbed from the back to the front and not with a circular motion?
6. Of what material are reflectors made?
7. Why are lenses used?
8. What precautions must be taken when inserting double-filament lamp bulbs?

Job No. 18

REPLACING LIGHT BULBS

Operations Necessary to Perform the Job.

1. Remove lamp cover.
2. Remove bulb.
3. Inspect bulb.
4. Replace with new bulb, if necessary.
5. Test lamp for operation.
6. Replace lamp cover.

Description of Operations.

Where the trouble is located in the light bulb, the repairman should open the lamp door, push back on the bulb firmly and turn it to the left until the pin on the base of the bulb lines up with the opening in the lamp socket, and then pull it forward out of the socket.

To inspect the bulb, hold it between the eye and the light and see if the filament is broken. If no break can be seen, test it by placing two

wires from a battery having the right voltage for the lamp on the two contacts and see if the light burns. If not, replace it with a new bulb.

Two-filament bulbs are becoming very popular for automotive illumination. The Ford head lights employ two-filament bulbs containing one filament for bright lights and one for dim lights. Other car manufacturers employ the two-filament bulb to project light ahead or, by means of a second filament, to cast rays on the road directly in front of the car.

After the bulbs have been tested and replaced, turn on the light switch and test the lights. If they do not light up, the trouble is in the switch or the wiring.

Questions.

1. How may you determine when the trouble is in the bulb?
2. If the filament in a light does not show a break and still the bulb does not light, how should it be tested?
3. Are there any differences in lights as to contacts and filaments? What differences?
4. What are the capacities in amperes which should be used for the different lights on the average car?
5. What precautions must be exercised when installing two-filament bulbs?

Job No. 19

REPAIRING AND CLEANING LIGHTING SWITCH

References.—Part Two, p. 469.

Operations Necessary to Perform the Job.

1. Locate trouble, using portable testing lamp.
2. If trouble is located in switch, remove cover and clean or adjust terminals as necessary.
3. Replace all parts.

Description of Operations.

If the repairman has tested the light bulbs and found them to be in good condition, or has replaced them and still they do not light, the trouble is either in the light wires or in the switch.

To locate the trouble use either the battery in the car or a substitute battery and a portable test lamp.

Attach one of the test-lamp wires to the same side of the battery to which the lead wire is attached, and follow the circuit throughout, one

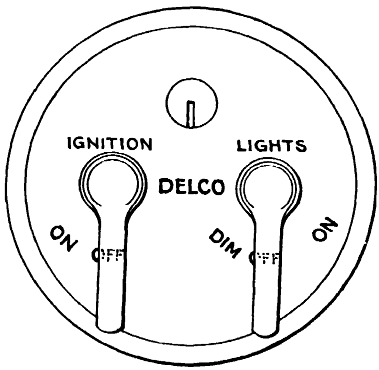


FIG. 19a.—Front View of Switch.

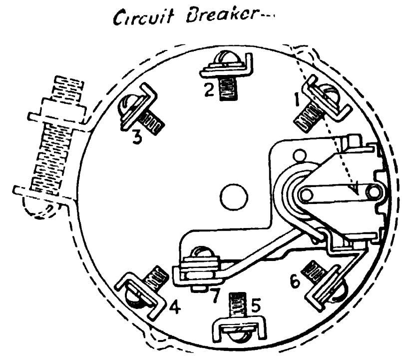


FIG. 19b.—Rear View Showing Terminals and Circuit-breaker.

step at a time, until the trouble is located. First test to and through the ammeter, then to the battery terminal on the switch; if the test light burns, the current is coming to the switch. Then throw the switch on and test the terminals that lead to the lights; if the light does not burn, the trouble is in the switch.

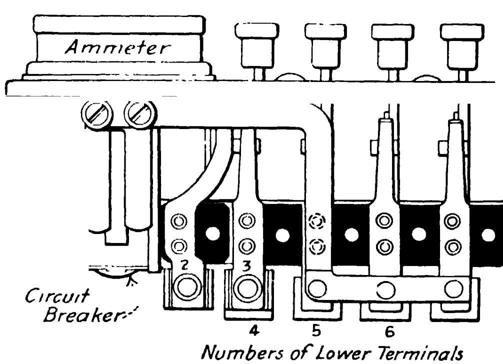


FIG. 19c.—Lighting and Ignition Switch Showing Terminals.

The two most common troubles in the switch are dirty or corroded connections in the switch and trouble due to bent blades. To repair the first trouble, clean the connections by scraping or by washing the parts with ammonia water; to repair the second trouble, spring the blades until they make a good contact, and then replace the switch cover.

Figure 19e shows a lighting and ignition switch which has an automatic circuit-breaker enclosed in the circuit.

To locate trouble, disconnect the wire *C* from the switch. Secure a long piece of wire and attach one end to the negative terminal of the storage battery. Press in on the button *a*, touch the free end of the wire to the spring *e*, and make and break the circuit. If a spark is given off, the contacts *c* are in good condition.

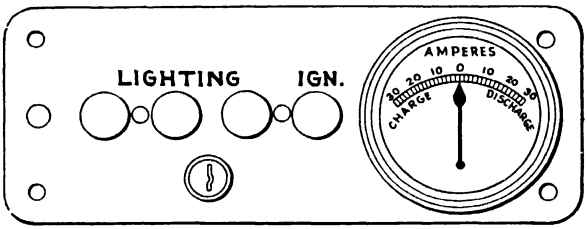


FIG. 19*d*.—Dash View of Fig. 19*e*.

If these contacts are in good condition, test the heat element *h* by bringing the free end of the wire up to the terminal *o*, and make and break the circuit. Failure to secure a spark at this point may be caused by the following conditions:

1. The heat element *h* may have burned out.
2. The wire *k* may have become unsoldered.
3. The heat element *h* may have become unsoldered from the spring *g*.

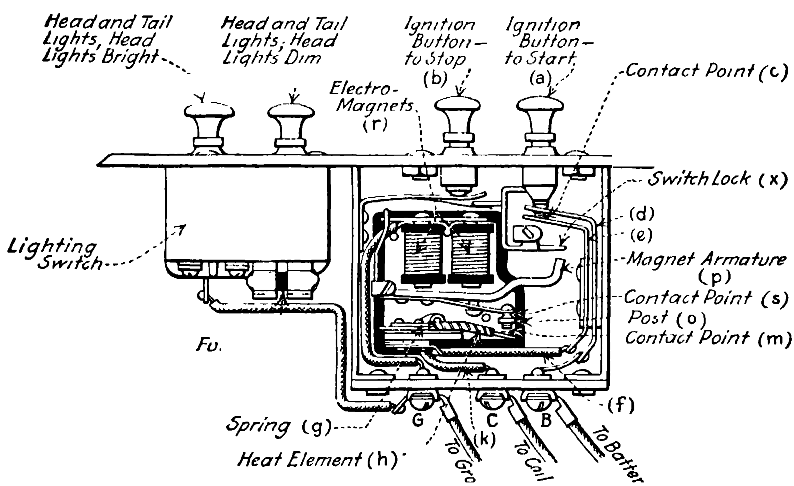


FIG. 19*e*.—Lighting and Ignition Switch. (Chevrolet.)

The second and third causes may be repaired readily, but if the heat element is burned out the switch should be sent to the nearest service station for repair.

A temporary repair can be made by soldering a short piece of wire from the terminal C to the spring e. However, extreme care should be used to push in upon the button b, when stopping the motor, or the battery will soon become exhausted.

When the circuit-breaker fails to act it may be due to poor contact between post o and point m, or to burned-out electromagnet coils. In this case, return the switch to the service station for repair at the first opportunity. The lighting switch is contained in an insulated case and will seldom need attention or adjustments.

Questions.

1. Where a test lamp is used on an automobile, what should be the voltage of the bulb?
2. What are the most common causes of trouble in a light switch?
3. What should be used in cleaning the contacts or blades of a switch?
4. What care should be taken in replacing the cover on a switch?
5. If a switch is burned out, how may you obtain light temporarily?
6. What is the principle under which the circuit-breaker in Fig. 19c operates?
7. What causes a fuse to blow?
8. How may a car be operated if the switch is locked "open" and you have lost your key?
9. Is the switch lock a good protection against theft?

Job No. 20

REPAIRING LIGHT WIRING TERMINALS

Operations Necessary to Perform the Job.

1. Test lighting circuits for loose or broken terminal contacts.
2. When located, clean and tighten same.
3. If lug is loose, sweat same on wire.

Names of Materials, Tools, Operations, and Care of Equipment to be Reviewed before Performing the Job.

Materials.—Solder paste, wire solder, waste.

Tools.—Soldering copper.

Parts.—Head lights and tail lights, circuits.

Operations. "Sweating terminals," soldering, testing for "loose or broken" terminals.

Care of Equipment.—Replace all wire terminals on correct connection; disconnect battery while making repairs.

Description of Operations.

If the lamps are in good condition and the switch shows a satisfactory test and still the lights are not burning, the trouble may be due to loose or broken contacts in the wiring terminals. These contacts may be at the switch, the fuse block, the junction block or the lights.

When the repairman finds contacts that have become loose and are covered with an accumulation of dirt and oil, he should clean the contacts with waste or soft cloth or by scraping.

Where the open circuit is due to broken connections or wires he should solder the wire, the connections, or the terminals to the wire. Where this is to be done the surfaces of the wire and the terminal should be cleaned with non-corrosive soldering paste, and then tinned by applying a thin coating of solder to the surface of each.

After the wire and lug are tinned, place them together in position and sweat the lug on by heating it with the soldering copper to the fusing point, taking care that the solder does not escape and that all points are fused together.

Questions.

1. What tools and material will be needed to repair loose or broken terminal contacts?
2. What should be used to clean dirty or corroded terminals?
3. What are the indications of a loose contact?
4. How may corrosion on battery terminals be prevented?
5. What is meant by the term "sweating" a terminal on a wire?

JOB No. 21

REPLACING OLD WIRES

Operations Necessary to Perform the Job.

1. If single unconcealed light wires are broken, or insulation is worn, they may be replaced or the insulation restored with rubber friction tape.
2. If a car is to be entirely rewired, it should be sent to a service station.

Description of Operations.

Do not attempt to take the electric lighting system apart unless you are an experienced repairman. If for any reason one of the lamps fails to burn, first inspect the filament and be sure that the lamp is not burned

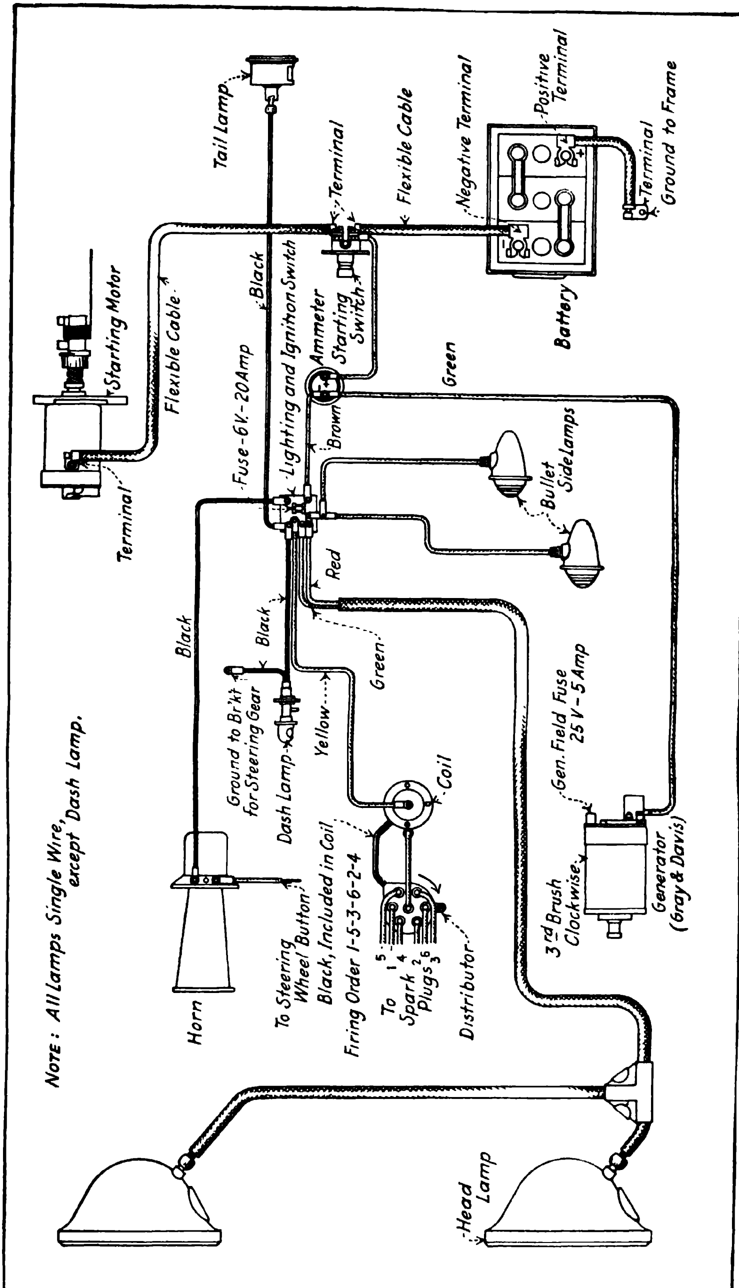


Fig. 21a.—Wiring Diagram Showing Single-wire System.

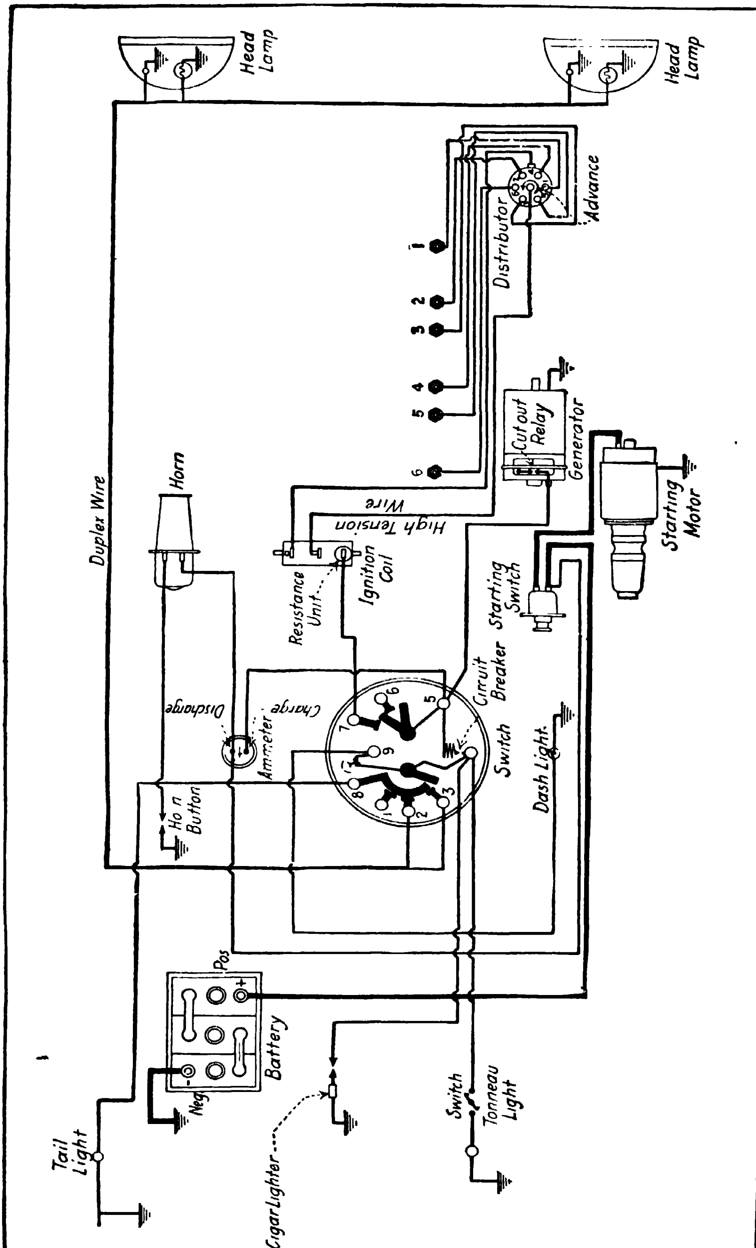


FIG. 21b.—Wiring Diagram Showing Two-wire System.

out. Next be sure that the lamp is tight in its socket, making the necessary contact. If the lamp appears to be in perfect condition, inspect the wiring and be sure that all connections are properly made and then examine the fuses to see if they are burned out. The fuses are usually located back of the dash under the cowl. A simple test can be made without disturbing the present wiring, by connecting a piece of insulated wire from the switch terminal to the light. If the lamp burns, the trouble lies between the switch and the lamp.

Sometimes small particles of dust work down between the fuses and the fuse clips so that simply rotating the fuse in the clips will often restore the circuit. Be sure the clips grasp the fuses firmly. If for any reason the horn fails to operate, inspect the wiring and connections in the same way as for the lights.

Where the lights, the switch, and the contacts are all in good condition and still the lights refuse to work, disconnect the wire leading from the lamps to the switch and substitute another wire of the same carrying capacity. This will show that the wire is broken or the insulation is worn if the light now burns. If the trouble is due to a broken wire the repairman may replace the wire with a new one, but when it is due to worn insulation the insulation will show a burned or chapped condition. In that case the repairman should wrap the wire where the insulation is worn with friction tape to insulate the wire. Where the car is to be entirely rewired the work should be sent to a service station.

Questions.

1. What is the quickest method of determining whether or not a new wire is needed?
2. What will be the appearance of the insulation where there is a ground?
3. Where the insulation is broken on a wire, how may it be restored?
4. How can you distinguish between a broken wire and one that is grounded?
5. Is it advisable for the average repairman to attempt to rewire a car entirely? If not, where should it be done?

Job No. 22

REMOVING STARTING MOTOR FOR A GENERAL OVERHAULING

References.—Part Two, p. 463.

Operations Necessary to Perform the Job.

1. Disconnect cable and wires.
2. Remove bolts.
3. Remove starter.

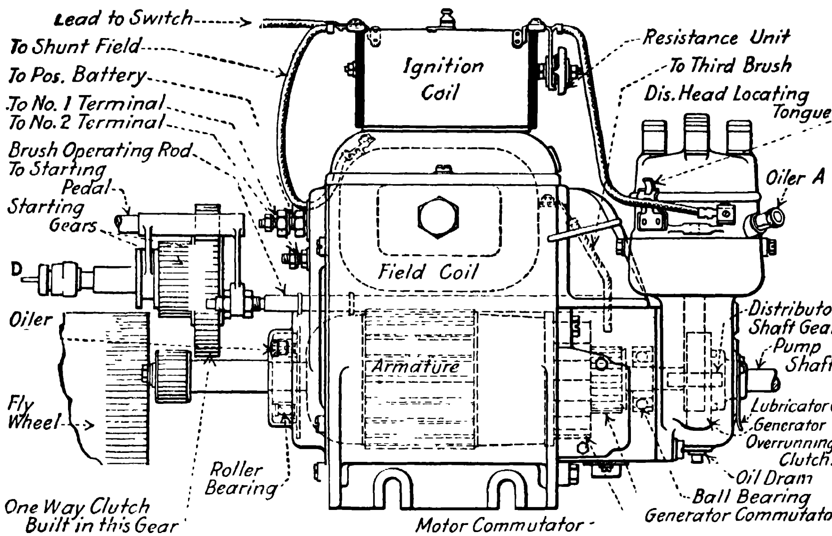


FIG. 22e.—Side View of Motor Generator.

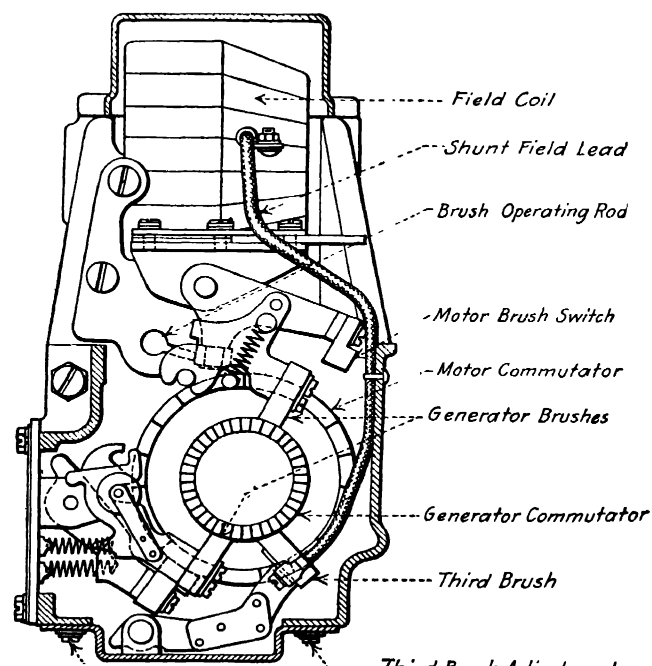


FIG. 22f.—End View of Motor Generator Showing Motor-brush Switch.

engine is running. It is usually located near and attached to the fly-wheel. Some makes, such as the Studebaker and Dodge, have the gear at the front end of the crank shaft. The Reo engages the main drive shaft back of the clutch.

If the repairman finds that the motor should be removed, he should first disconnect the battery at one terminal. Usually it is quicker to disconnect the negative side as it does not stick to the cable as tightly as the positive and usually is the cleaner of the two on account of the corrosion on the positive.

In disconnecting the cables, it is best to mark the end of each and the terminal from which it is taken so as to replace it in the same position. Except where the repairman has made a special study of motors and generators, it is inadvisable for him to attempt to take down and repair internal trouble in either.

In sending a motor to a service station, if possible always send it to an authorized station for that particular make of machine. When it is returned, reinstall the motor in its former position and test its operation.

Questions.

1. Where the battery cables are disconnected from a motor, what precaution should be taken to prevent a "short circuit"?
2. If one of the cables is to be disconnected from the battery, which one should be removed first in order to prevent a "short circuit"?
3. Should pliers be used to remove nuts from bolts?
4. Does the battery current which operates the starting motor pass through the ammeter?
5. Approximately how many amperes are required to operate the starter?
6. What is the average horsepower of a starting motor?
7. Why is a high current strength required?
8. What is meant by a unit generator and starter?
9. What is the principal difference in the construction of the unit and dual types?
10. Can all motors be used as generators?

Job No. 23

REPAIRING OR REPLACING STARTING SWITCH

Operations Necessary to Perform the Job.

1. Where starter switch is a unit in itself, remove it from the car and clean parts.
2. Repair parts or replace as necessary.
3. Replace switch on car.

4. Where switch is located inside of starter housing, the job should be sent to a service station.

Description of Operations.

Where the starter switch is a unit in itself the repairman will generally find it located under the floor boards as shown in Fig. 23*a*. It is connected by cables of heavy wire attached to each side of the switch, one of which leads to the battery and the other to the starting motor (" *S*," Fig. 22*d*).

When it becomes necessary to remove the switch to make repairs it is well to tape one end of this cable or disconnect the battery to prevent a " short circuit " on the battery in case the cables get together or come in contact with the frame. The only conditions that make necessary the removal of the starter switch are oily or dirty parts, or blades that have become bent, burned, or broken.

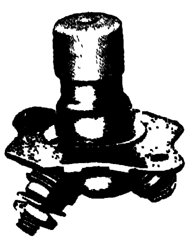


FIG. 23*a*.—Starting Switch.

Where the switch is found to be oily or dirty it may be cleaned by washing in ammonia water, gasoline, or kerosene.

Where the blades are bent but not cracked, it may be possible to repair them by straightening the blades and then bending them back to their original position.

Where it is necessary to replace parts, new parts should be secured from a service station.

After the switch is repaired and cleaned, replace it, being careful to get it back in its former position with all bolts drawn up tight.

If the starter switch is located inside of the starter housing, as is the case in some Delco, Bosch, and other makes of starters, it is best to send the motor to an authorized service station for repairs.

Questions.

1. What might cause the starter switch to need repairing?
2. Where the starter switch is to be repaired, what precaution should be taken to prevent a possible " short " on the battery?
3. What might cause a starter switch to stick?
4. What will be the result of a "short" or "ground" in the starter switch?
5. How is the switch shown in Fig. 22*c* made to operate?
6. If the end of the cable running from the battery to the switch makes electrical contact with the frame or other metal parts of the car, what damage may result?

Job No. 24

REPAIRING A "BENDIX" DRIVE

References.- Part Two, p. 466.

Operations Necessary to Perform the Job.

1. Inspect drive to locate trouble.
2. Clean worm.
3. Replace same if worn out.
4. Replace spring if broken.
5. If spring is loose, tighten bolt.

Description of Operations.

In the " Bendix Drive " (Fig. 24*a*) there is no mechanical connection with the starting button. With this type of drive the starting pinion is

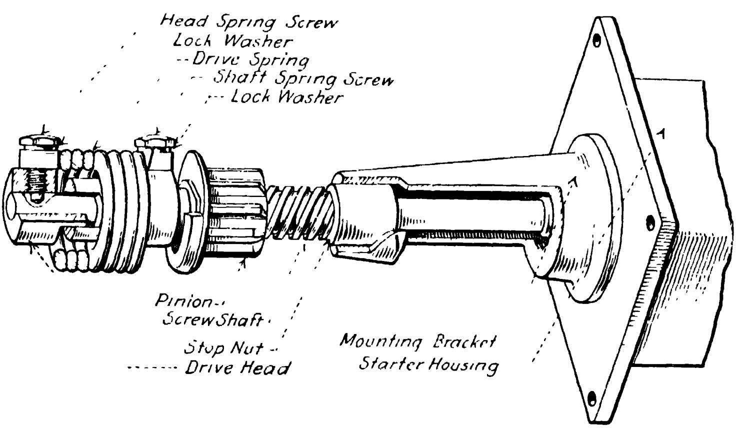


Fig. 24*a*.—Bendix Drive.

mounted on a spiral at the end of the armature shaft. When the current is applied to the starting motor the armature shaft revolves, while the inertia of the weighted starting pinion tends to keep it from rotating. This causes the armature shaft to be screwed into the starting pinion, thereby drawing the latter into engagement with the teeth on the flywheel gear. As soon as the engine starts to run on its own power the flywheel drives the starter pinion at a higher speed than the armature shaft is revolving. This motion unscrews the pinion on the shaft until it is entirely out of mesh with the flywheel gear.

The heavy spring at the end of the armature shaft cushions the engagement of the starting pinion as it starts to drive the flywheel. The action of the Bendix Drive is entirely automatic and it requires no care except through lubrication of the spiral on which the pinion travels.

Occasionally the starter pinon and the flywheel gear do not mesh properly, but lock. If this occurs, put car in high gear and rock car backward with clutch engaged and brakes released. Usually this will release the gears.

Sometimes the pinion strikes a flywheel tooth squarely and binds on the spiral. It can be released by turning the motor with the starting crank. If the pinion should become stuck on the spiral it will not

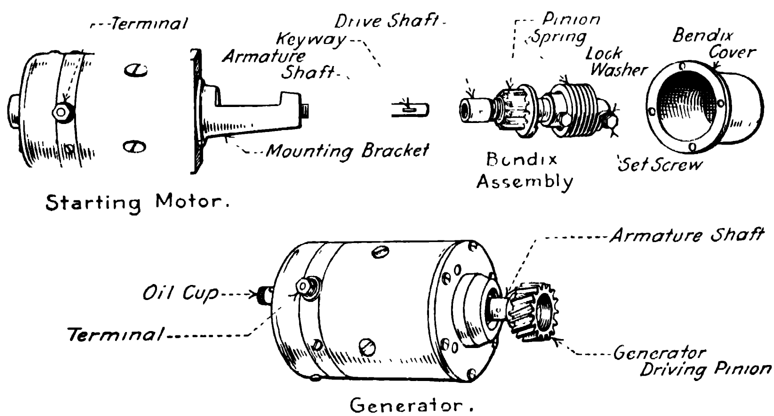


FIG. 24b.—Starter and Generator Units.

engage. It may be freed by cleaning thoroughly with kerosene and then lubricating.

With this type of starting motor the foot should be released from the starting pedal just as soon as the engine starts, otherwise unnecessary current will be consumed. Never start the motor with a full advanced spark, as it will prevent the starter from turning the motor and result in a broken Bendix spring.

If a starting motor having a Bendix Drive operates but does not crank the engine, the trouble is due to a broken spring, a stripped pinion, a dirty threaded sleeve, a broken bolt, or a counter weight which is too light and allows the pinion to spin with the armature shaft.

To locate these troubles the repairman should check up all the foregoing parts and see that all are in a good mechanical condition.

Where the coil spring is broken, it will be necessary to remove the

spring by detaching the two bolts that hold the spring to the armature shaft and threaded sleeve and to replace it with a new spring. Be certain that the new spring is for left or right rotation, as the case requires.

Where the pinion is stripped or broken, remove the spring and thimble that holds the pinion and replace the pinion with a new part.

Where the threaded sleeve is dirty, clean it with waste dipped in gasoline or kerosene.

If the bolts are broken, replace them with new bolts; where the threaded sleeve is worn or broken, repair it by installing a new sleeve.

Questions.

1. What are the most common causes of trouble in a Bendix Drive?
2. What will cause the pinion on a Bendix Drive to "climb" on the flywheel of an engine?
3. What may cause a Bendix Drive to stick?
4. If the pinion on the drive fails to engage the flywheel when the armature is turning over, what is wrong and how may it be repaired?
5. What may be done in case the pinion of the drive engages the flywheel while the car is running?
6. What are some other types of drives? (See Fig. 22*c*.)
7. What are some of their advantages and disadvantages?
8. Where are starters attached on Model T Ford cars?

Job No. 25

REPAIRING OVER-RUNNING CLUTCH ON MOTOR OR GENERATOR

References. Part Two, p. 465.

Operations Necessary to Perform the Job.

1. Remove clutch from shaft, using pullers if necessary.
2. Take clutch apart and clean.
3. Install new oversize rollers.
4. Replace springs if necessary.
5. Reassemble clutch.
6. Replace on car.

Names of Material, Tools, Parts, and Care of Equipment to be Reviewed before Performing the Job.

Material.—New rollers and springs for clutch.

Tools.—Gear puller.

Parts.—Outer ring, clutch center, rollers, plungers, springs, inner sprocket.

Description of Operations.

The over-running clutch (Fig. 25*a*) is used between the pump shaft on the engine and the armature. Its purpose is to allow the armature to run faster than the pump shaft, but to prevent the pump shaft from turning faster than the armature.

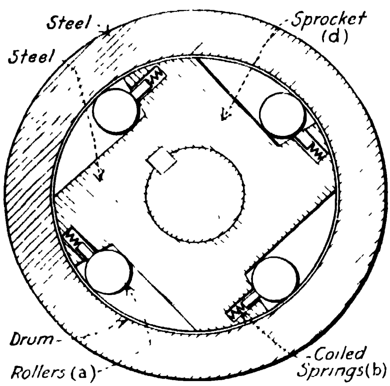


FIG. 25*a*.—Over-running Clutch.

The inner sprocket *d* is attached to the armature shaft by a Woodruff key to prevent turning on the shaft and by a castellated nut to hold the clutch on the armature shaft.

The clutch fits with a driven fit, and sometimes it will be necessary to pull it off with a gear puller.

In disassembling the clutch, remove the screws and take off the cover plate, force the rollers *a* back against the springs *b*, and lift out the inner sprocket *d*, taking care not to drop rollers *a* and springs *b*.

Where the clutch slips, the repairman should replace the rollers if necessary, and where the springs are weak or broken they should be replaced. The parts should then be reassembled, and the clutch filled with grease and replaced on the car.

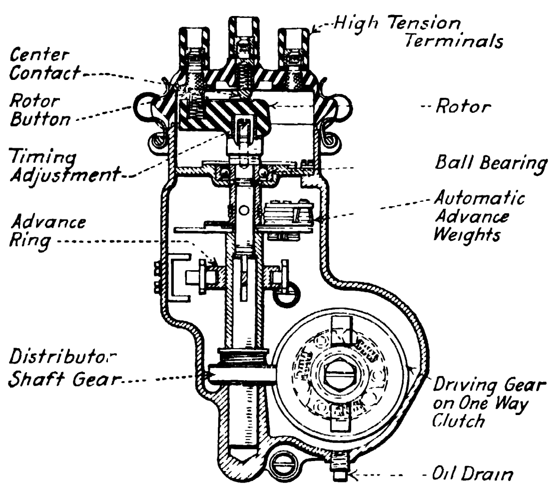


FIG. 25*b*.—Over-running Clutch on Delco Generator.

If the rim or outer race of the over-running clutch is used to drive

the ignition gear, the ignition must be timed to the engine when the clutch is replaced.

Questions.

1. What might cause the over-running clutch to "slip" or fail to engage?
2. What is the purpose of the over-running clutch on a motor or generator?
3. Where is the over-running clutch used?
4. If the over-running clutch should fail to engage on a generator, what would be the result on the battery?
5. What kind of lubrication should be used on the clutch?
6. In Fig. 22*c* where is this type of clutch used?
7. Will the over-running clutch "grab" or is its operation flexible?
8. In the over-running clutch shown in Fig. 25*b*, does the shaft connect to the timer?

Job No. 26

INSULATING STARTING CABLE

Operations Necessary to Perform the Job.

1. Remove cable if necessary.
2. Clean cable.
3. Wrap cable with friction tape.
4. Replace cable on terminals.

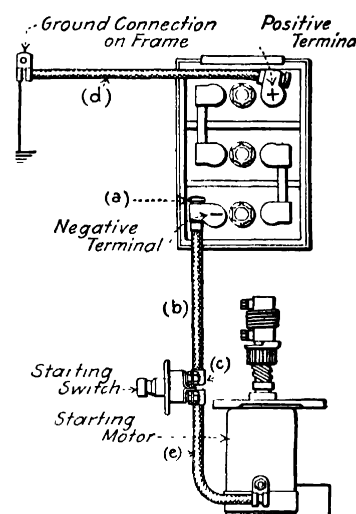


Fig. 26*a*.—Starting Cable.

Description of Operations.

Before working on the starter circuit, disconnect one side of the battery *a* (Fig. 26*a*) to prevent a possible "short circuit."

If the wire *b* is "shorted or grounded" the wire should be cleaned by washing it with rags soaked in kerosene until the wire and the insulation are entirely free from grease and dirt. After the wire is dry it should be wrapped with friction tape to insulate the point of contact.

A coat of shellac applied to the tape will prevent grease from loosening the tape. Wind cord around tape to prevent unwinding.

If the wire is in a place where it is hard to get at, it should be removed. Disconnect at *c* and *a*, pull the wire out, make the needed repairs, and replace the wire, making certain to get good connections at both *c* and *a*.

The work would be the same if the trouble were in the wire at *d* or *e*.

To prevent chafing of the insulation of cables, enclose them in a piece of loom. Loom can be secured from an electrical supply house. Oil does not damage loom readily.

Questions.

1. What might necessitate the removal of a starting cable from a car?
2. What is used to clean the insulation on a starter cable?
3. What may be used as an insulation on a cable if the insulation is broken or burned?
4. What might cause the starting cable to break at a battery post? How may it be prevented?
5. What will be the result on the starting circuit if there is a loose connection on the battery?

Job No. 27

CLEANING AND ADJUSTING AN ELECTRIC WARNING SIGNAL

Operations Necessary to Perform the Job.

1. Press button and note tone of signal.
2. Determine from tone if there is need for adjustment.
3. If signal does not respond, press button again and note if current reaches it.
4. If current does not reach horn, inspect fuse, button, and wiring.
5. Clean and inspect commutator and brushes and oil bearings, if horn is motor-driven. Clean and adjust points, if a vibrator warning signal is employed.

Names of Materials, Tools, and Parts to be Reviewed before Performing the Job.

Materials.—Sandpaper, light oil, fuse.

Tools.—Screw driver, pliers, wrench, undercutter, adjusting wrench, point file.

Parts.—Button, motor, commutator, vibrator, diaphragm, ratchet wheel, projector, fuse, clip, magnets.

Description of Operations.

Electrically operated warning signals can be classified as motor-driven and vibrator types. Poor tone, slow response, or failure to respond to

the pressing of the button indicates that the signal requires attention. An open circuit, caused by poor contact in the button, a broken conductor, or a blown fuse, will render the horn inoperative.

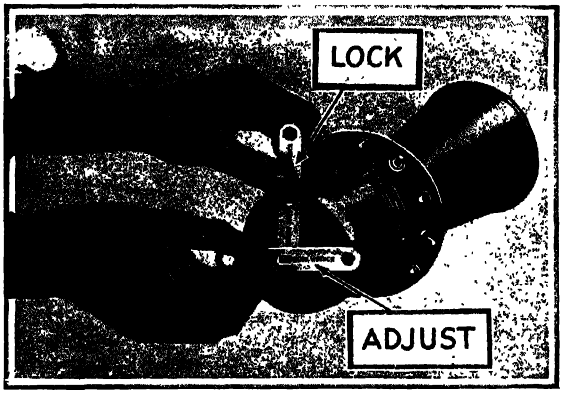


FIG. 27*a*.—Vibrator Horn Adjustment.

To clean the horn, remove the inspection cover and examine the horn brushes and commutator, if a motor horn, and wipe any excess oil, gum, or dirt from them. If the horn is a vibrator type, clean and adjust the vibrator points so as to produce the normal sound. (See Figs. 27*a* and 27*b*.)

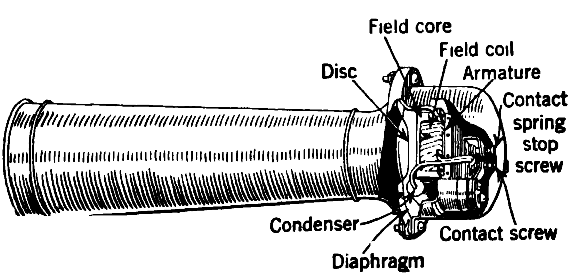


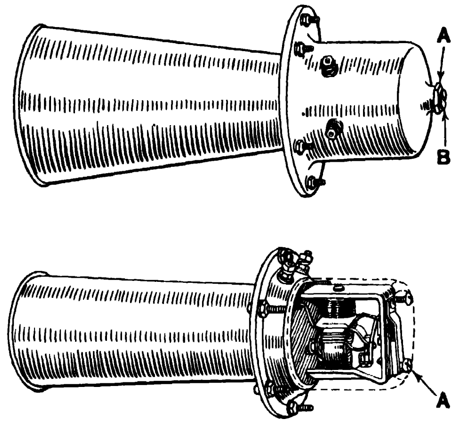
FIG. 27*b*.—Parts and Adjustments of Vibrator Horn. (Klaxon.)

To adjust a motor horn, move the armature and ratchet wheel toward or away from the diaphragm by means of the adjusting screw at the rear of the horn (Figs. 27*c* and 27*d*), and oil the bearings with a few drops of very light oil. By experiment, determine the kind of adjustment necessary to secure the desired tone, and turn the screw clock-

wise or counter-clockwise slowly until the tone is clear and the horn responds readily when the horn button is pressed. Lock all adjustments carefully.

To Oil. — Remove motor cover. Oil once a month, as shown on the illustration.

To Clean Commutator.— The commutator should be cleaned once a month. Set the motor in motion by pressing the push button, and clean



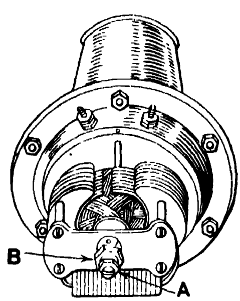


Fig. 27c.—Motor-horn Adjustment. (Klaxon.)

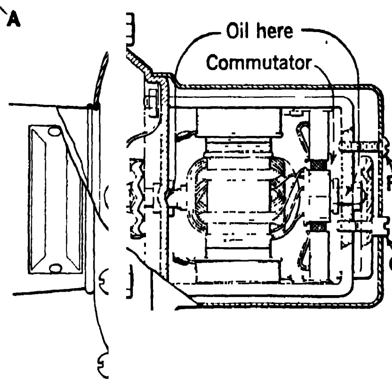


Fig. 27d.—Motor-horn Care and Adjustments. (Spartan)

the commutator with soft cloth saturated with three-in-one oil. If the commutator becomes dry, use a few drops of three-in-one oil only.

To Adjust Tone.—Insert a screw driver into screw *G* and tighten or loosen to obtain the desired tone.

Questions.

1. What is a vibrator horn? A motor horn?
2. What is a diaphragm?
3. Why do vibrator points require occasional cleaning?
4. Is heavy oil suitable for motor-horn lubrication? Why?
5. If the armature of a motor horn binds, what is wrong?

CHAPTER IV

TROUBLE SHOOTING

Job No. 1

ADJUSTING CARBURETOR

References.—Part Two, p. 477.

Operations Necessary to Perform the Job.

1. Inspect quantity of fuel in tank.
2. Open drain cock at bottom of carburetor or flood carburetor, to determine whether enough gas reaches the carburetor, and to remove any foreign substances present.
3. Inspect choke, adjustment, throttle, and spark controls.
4. Start engine and warm up thoroughly.
5. Accelerate and throttle engine to determine necessary adjustments.
6. Examine fuel-supply lines and units, if carburetor empties and engine stalls.
7. When assured that sufficient fuel is being delivered, determine change of adjustment necessary, by operating the engine at high and low speeds.
8. Retard spark and close throttle. Engine exhaust at muffler tail pipe should be even and regular.
9. Manipulate low-speed adjustment until engine throttles smoothly.
10. Set high-speed adjustment so that carburetor does not emit a "popping" noise, exhaust does not discharge clouds of black smoke when throttle is opened, and engine picks up speed rapidly.
11. If satisfactory results are not obtained, remove, clean, adjust, and test spark plugs, and examine spark plug cables; examine breaker-distributor and check ignition timing.
12. Engine may cease to fire when higher speeds are reached, but no popping will be present. Remove a spark-plug wire and hold $\frac{1}{4}$ inch from cylinder. If spark does not jump regularly at high speed, inspect or replace coil and condenser.
13. Run engine and test same again.
14. If operation has not improved, test compression, check valve adjust-

ments, inspect valve guides for wear and air leaks, check tension of valve springs, and inspect manifold joints for air leaks.

15. Remove and inspect carburetor. Compare numbers of metering pin, jets, and venturi with manufacturer's specifications; clean, assemble, and replace carburetor and new gaskets.
16. Test engine again; if satisfactory adjustment cannot be made, check valve timing.
17. If correct low-speed adjustment can be made, proceed to adjust high speed.
18. Test car on road and adjust to eliminate any "light spots" or "loading up" if present.

Names of Materials, Tools, Parts and Special Terms to be Reviewed before Performing the Job.

Materials.—Gasket material, shellac, emery cloth, cotter keys.

Tools.—Wrench, file, scale, hammer, pliers, screw driver.

Parts.—*Carburetor* and *Inlet Pipe.*—Carburetor, inlet manifold, inlet pipe, inlet manifold or pipe gaskets, carburetor gaskets.

Carburetor Control.—Accelerator pedal, accelerator pedal bracket, accelerator pedal pin, accelerator pedal rod, accelerator pedal rod-end pin, carburetor mixture hand-regulator, carburetor choke.

Carburetor Air-heater.—Carburetor air-heater, carburetor hot-air pipe, air cleaner, hot spot.

Fuel Tank.—Fuel tank, fuel reserve tank, fuel gauge, fuel-gauge float, fuel-gauge glass, fuel-tank outlet strainer, fuel-tank outlet flange fitting, fuel-tank pressure flange.

Fuel Pipe and Feed Systems.—Main fuel valve, reserve fuel valve, fuel-pipe main tank to auxiliary tank, fuel pressure-pump, fuel hand-pump, fuel pressure-gauge pipe, fuel pressure-gauge tee. Fuel pressure pipe to tank, fuel pressure-pump pipe, fuel hand-pump pipe, fuel hand-pump tee, fuel pressure gauge.

Special.—"Lost motion," "backlash," "popping of carburetor," "loading up," "light spot," "roll."

Description of Operations.

A carburetor is a metering device, the function of which is mechanically to blend a liquid fuel with a certain amount of air to produce as nearly homogeneous a mixture as possible, and in such proportions as will result in as perfect an explosive mixture as can be obtained.

If a gas is used as the fuel, it is not so difficult to obtain a homogeneous mixture, because of the intimacy with which a gas will mechanically mix with air. With a liquid fuel such as gasoline, it is the aim of all

carburetor manufacturers to produce an instrument which will atomize the fuel and break it up into as small particles as possible, so that every minute particle of the fuel will be surrounded by a correct proportion of air when it is discharged into the combustion chambers of the engine. To facilitate the vaporization of these minute particles of fuel, it has been found advisable to preheat the air taken into the carburetor, thereby furnishing the necessary units required to vaporize the fuel by virtue of its latent heat of evaporation. Manifold "hot spots" heat and vaporize the mixture after it leaves the carburetor.

An elementary requirement of a carburetor is that, as a metering device, it shall properly proportion the gasoline and air throughout the entire operating range.

Adjusting carburetors is one of the most difficult jobs connected with the upkeep of an automobile unless the operator or repairman has had considerable previous experience. Where many different types of carburetors are to be adjusted, frequent reference should be made to the manufacturer's instruction hand books for specific information applying to the particular model used.

The general principles of carburetion are the same for all gas engines, but the mechanical devices used to obtain the best working conditions vary with the different types of carburetors. In discussing this job a general description of the operation is first given, followed by instruction for several different types of carburetors:

To test its operation, start the engine and warm up thoroughly. Indications of too rich a mixture are as follows: engine exhausts black smoke; exhaust has rich gasoline odor; engine runs slowly and sluggishly; engine overheats; carburetor floods; engine lacks " pep " or will not speed up. Indications of too lean a mixture are as follows: popping in the carburetor; engine stalls; engine develops speed, but lacks power.

Fuel troubles are generally due to water in the gasoline, a poor grade of gasoline, no gasoline in the tank, filter trap stopped up, carburetor screen dirty, obstructions in feed pipe, gasoline leaks, or failure of the vacuum or gas delivery system. If adjustment is necessary, examine all controls for correct position. If a dash control is used, the lever should be set at its running position with the air-choke valve located on the carburetor open. If the flushing or flooding pin located on the float chamber cover is stuck, it should be released. If the carburetor has a priming device, it should not be in use when the carburetor is being adjusted. If the auxiliary air valve operates at low speed, change the adjustment to keep the valve closed.

After inspecting all controls for their correct position and after making such changes as are found to be necessary, with the engine run-

ning, the spark retarded, and the throttle almost closed, adjust the carburetor by regulating the gasoline or air to a richer or leaner mixture until the engine runs best at low speed. A steady, even exhaust on all cylinders, with the engine responding to a sudden opening and closing of the throttle by instantly changing its speed, is necessary.

If the above conditions cannot be obtained, test a spark plug for a weak spark. Hold the end of the secondary cable about $\frac{1}{4}$ inch from the cylinder while the engine is running. A good spark should jump the gap regularly.

Remove the spark plugs and inspect, clean, and adjust them as in Job No. 4, page 173. If drops of water are detected on the insulation of spark plugs, inspect the cylinder head and gasket for water leaks. Examine the breaker points; clean, adjust, and time the opening as in Job No. 3, page 166. Examine all secondary cables for leaks or breaks in the insulation. Replace all broken wires.

Inspect the spark-control rod, leading from the interrupter or distributor to the lower end of the steering column, for lost motion.

If the trouble is not yet located, examine the intake manifold for air leaks, the valve-stem guides for air leaks due to wear, and the carburetor filter screen for water or dirt.

While making these examinations, test the condition of the float valve and the gasoline in the tank, and drain the trap in the gasoline line. The spray nozzle, metering pin, fuel jet, or distributor should now be tested for correct size and for an obstruction to the flow of gasoline.

If the cause of the trouble has not yet been located and a vacuum tank is used, it should be tested for a defective float assembly (see Job No. 4). Trouble oftentimes may be located in leaky gaskets or in clogged filter screens and air vents. Sometimes gasoline contains water or sediment which may collect in the tank and stop the flow of gas.

After all these inspections and tests have been made, reassemble all parts, start the engine, and again try to make the low-speed adjustments on the carburetor.

If a correct adjustment for low speed cannot be made, stop the engine, remove the carburetor from the manifold or the cylinder block, and check the carburetor as to correct size and general conditions. Check level of gasoline in float chamber. The level should be about $\frac{1}{32}$ inch below the tip of the spray nozzle or jet. While making this examination it is well to examine the valve tappets, lifters, push rods, and rocker arms for clearance and correct adjustment. The clearance when adjusting valves should be from .003 to .008 inch or according to the manufacturer's specifications.

A condition commonly known as " loading up " is sometimes present. The symptom of " loading up " is irregular misfiring or " galloping action," present when the engine has been throttled for a few minutes and is then accelerated. When this condition is present, the engine will operate evenly after the throttle has been partially open for a short period. The absence of a hot-air intake pipe, failure of the exhaust gases to circulate around the carburetor jacket or "hot spot," or an over-rich mixture will cause loading or excessive condensation of gas in the manifold.

Uneven operation at low speeds is usually caused by wrong carburetor adjustment, manifold air leaks, wrong spark-plug adjustment, breaker out of adjustment, poor compression, worn valve guides or weak valve springs.

A defective coil or condenser or burned and pitted breaker points produce a weak spark. A small, flimsy spark will cause an engine to pop back in the carburetor although the mixture is correct, and sometimes will cause an engine to cease firing after a reasonably high engine speed has been attained and then resume firing after it has slowed down.

The car should be given a road test to make sure it is performing correctly. Very often " light spots " exist when the throttle is opened, and the car does not pick up within a certain range of the opening of the throttle. Slight adjustments usually remedy this condition.

As a means of obtaining specific information in making these adjustments, the following description of séveral types of carburetors is included.

In the Model MB-1 Stromberg carburetor the mixture proportioning is maintained by the use of what is termed the " Air Bled Jet." At high speeds the gasoline, after passing the orifice F (Fig. 1a) is mixed with air taken through the bleeder G and holes in H to form a highly atomized mixture which passes through passage N to eight discharge holes in the small venturi I.

At low speed the gasoline does not enter the venturi but is taken through the hole J to a point above the throttle, entering through the idling jet K. The accelerating well M serves as a reservoir, which discharges on acceleration and refills on deceleration.

After satisfactory performance, the motor may become erratic in its action. While the difficulty may be the result of an improperly adjusted carburetor, it may also be due to other causes, and it is advisable to look elsewhere before disturbing the carburetor adjustment. The adjustments should only be changed with changes in fuel or extreme changes in temperature.

There are two adjustments on the Model MB-1 Stromberg car-

buretor. The screw *A* (Fig. 1*b*) is the main adjustment which controls the gasoline supply from the float chamber and regulates the mixture throughout the whole driving range, and which should be set in the position where the best power and quickest "pick up" are obtained. The needle is raised and the supply of gasoline thereby increased by turning the nut *A* anti-clockwise or to the left. When turned clockwise, or to the right, the needle is lowered and the supply decreased. Should an entirely new adjustment be necessary, the nut *A* must be turned clockwise until the needle is just seated; it should then be turned

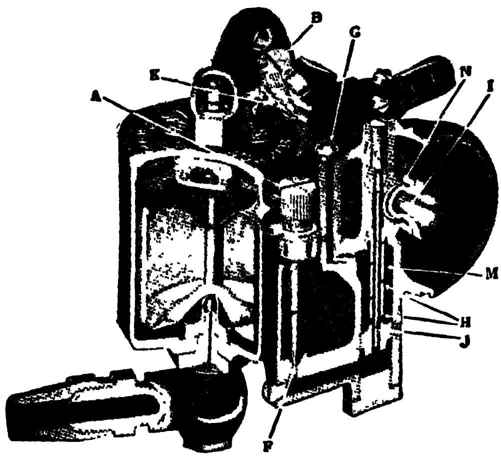


Fig. 1*a*.—Stromberg Carburetor Type MB-1. (Sectional View.)

A. High-speed adjusting screw
B. Low-speed adjusting screw
F. Orifice admitting gasoline to main channel.
G. Air bleeder
H. Small holes in accelerating well
I Small venturi tube
J Gasoline entrance hole to idling tube.
K Idling discharge jet
M Accelerating well space
N. Gasoline channel to small venturi tube.

to the left, or anti-clockwise, three complete turns. This setting should allow a rich mixture which can be regulated as necessary for the best driving mixture when the engine has been started and allowed to become warm.

When the engine is idling, the gasoline is taken in above the throttle and controlled by a dilution with air from the inside of the carburetor, as regulated by the screw *B*. This screw should be set between $\frac{1}{2}$ and $1\frac{1}{2}$ turns to the left, or anti-clockwise, from the seating position. When the engine is warmed the supply of gasoline may be increased by turning the screw clockwise or decreased by turning it anti-clockwise, as is found necessary. This idling adjustment is effective only when the throttle is nearly closed.

When starting and warming the engine with present-day fuel, it is absolutely necessary to use the dash control until the proper operating temperature is attained. Ordinarily the engine will start readily when the control is closed about one-half of its full distance; however, during very cold weather, it may be necessary to pull up on the control for the full distance. The control should remain out only for an instant, as the air supply is entirely cut off and only raw gasoline is being delivered.

When the engine has been started the control should be adjusted as found necessary. After allowing the engine a moment to adjust itself,

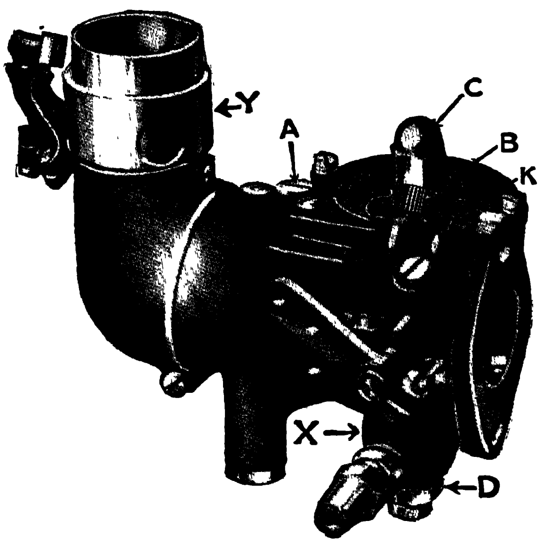


FIG. 1b.—Stromberg Carburetor Type MB-1.

A. High-speed adjusting screw.
B. Low-speed adjusting screw.
C. Needle valve cap.
D. Strainer body drain plug.
K. Idling discharge jet.
X. Strainer body.
Y. Season air adjustment.

the control should be set at the point where the full power will be obtained with the mixture sufficiently lean for smooth running. As the engine becomes warm the control should be lowered.

The season-adjustment shutter on the carburetor, where the hot-air pipe is attached, should be closed during winter months and during warm weather should be opened to admit cool air.

The Marvel Carburetor.—The construction of the Marvel Carburetor embodies a main body or mixing chamber and a conventional float-chamber bowl with fuel strainer attached at the point of entrance of the fuel to the bowl. Within the mixing chamber are two nozzles which proportion the amount of gasoline used in the mixture. One of

these nozzles, called the "low speed," is regulated by the gasoline-adjustment needle at the bottom of carburetor, and the other, called the "high-speed," is controlled by the automatic air valve. An air-adjustment screw regulates the pressure of the air-valve spring enclosed therein. Within this screw is also enclosed a plunger connected by a link to the air valve. The function of this plunger is to provide a resistance in addition to that of the air-valve spring to assist in acceleration. This arrangement of plunger and air-valve screw is called the " dash-pot."

A further control of the high-speed jet is provided by the fuel-metering valve, operated by the carburetor throttle. This valve provides the maximum fuel feed to the " high-speed " nozzle when the throttle is fully opened for high speeds and for a quick " pick up." In the ordinary driving ranges this valve controls the amount of fuel being used, thus providing all the economy possible. This valve is entirely automatic and requires no adjustment.

A choke button is provided on the instrument board to assist in starting. Pulling out this button closes a butterfly valve in the air-intake passage of the carburetor, which restricts the air opening of the carburetor and consequently produces a richer mixture.

A control lever is also placed on the instrument board to provide for manual regulation, in addition to the automatic heat-control mechanism of the carburetor.

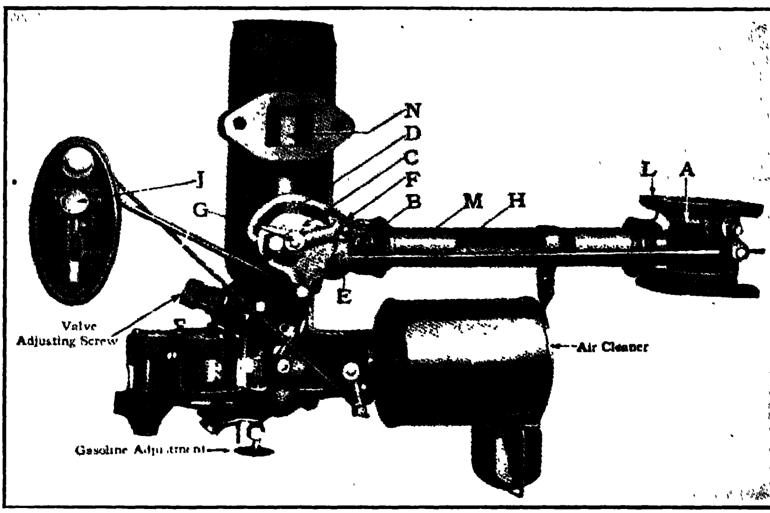
Heat Control.—The carburetor and manifolds have been designed to utilize the exhaust gases of the engine to insure complete vaporization and a consequent minimum consumption of fuel. This is accomplished by the use of a double-walled riser between the carburetor and the intake manifold. The riser is connected to the exhaust manifold in such a manner that the exhaust gases pass between the walls of the riser and through an outlet tube back to the exhaust pipe. The amount of heat thus furnished to the riser and carburetor is controlled by two valves, one in the exhaust pipe and one in the outlet tube of the riser heat jacket.

The valve in the exhaust pipe is connected to the throttle lever of the carburetor in such a manner that the greatest amount of heat is had in the riser when the throttle is only partly open, as in idling and at slow speeds, and a decreasing amount as the throttle is opened farther for higher speeds. By means of the heat control lever on the instrument board, this automatic action of the heat valve may be varied to suit weather and driving conditions.

The control lever also operates the valve in the outlet of the carburetor riser simultaneously with the valve in the exhaust pipe, and adjustment may be had to the point where no exhaust gases pass through the riser.

Starting.—To start the engine, pull out the choke button all the way, set the heat-control lever at the top or "heat on" position. Advance the spark lever about halfway, with the throttle lever about one-quarter way, and depress the starter pedal.

The moment the engine fires, the choke button should be pushed in about three-quarters of the way and allowed to remain in that position until the engine is running smoothly. After the engine has warmed up, the choker should be pushed in all of the way and the heat-control lever



FGI. 1c.—Marvel Carburetor Showing Heat Lever at " On " Position.

Heat-control lever *J* on instrument board at No 1 or "heat on" position Valve *A* in main exhaust pipe closed and valve *B* in outlet of carburetor body wide open Gases from exhaust manifold enter at opening *N* and pass through riser jacket, returning to exhaust pipe below valve *A*.

As throttle is opened, valve *A* remains closed up to approximately 40 miles per hour and then opens with wide-open position of throttle

set in any position between the top and the middle of the slot, depending upon weather conditions and the character of the driving to be done.

It should be remembered that the position of the heat lever largely controls the " pick up " and acceleration of the car. Therefore, if driving in traffic where a quick acceleration is desired, drive with the heat-control lever between " heat on " and " medium," never below " medium " in town driving, for best all-around performance. On straight-away driving, the heat lever may be set to " medium." Only in extreme cases of very hot weather should it ever be set at the bottom or " heat off " position.

Adjustment.—No change should be made in the carburetor adjustment until after an inspection has been made to determine if the trouble is not in some other engine unit. Care should be taken to see that the vent hole is open in the filler cap of the main tank; that the gasoline lines are clear; that there is gasoline in the gas supply line; that there are no leaks at the connections between the carburetor and the engine; that the ignition system is in proper condition; and that there is an even compression in all cylinders.

If it is necessary to test the adjustment or to make a readjustment, proceed as follows:

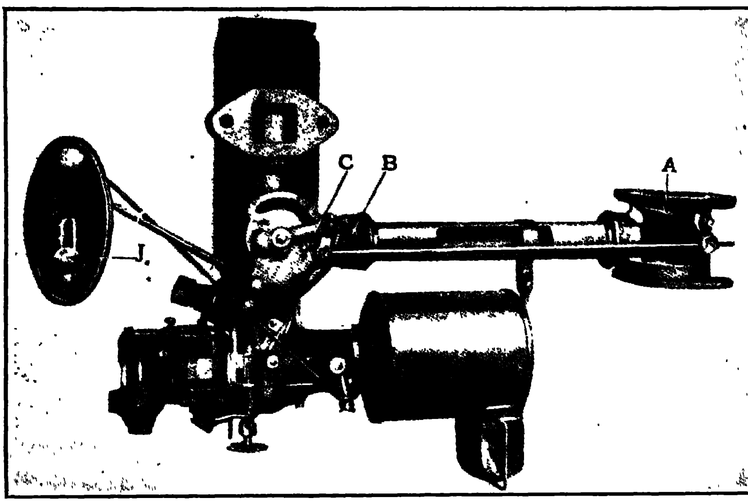


Fig. 1*d*.—Marvel Carburetor Showing Heat Lever at "Medium Position."

Control lever *J* on instrument board in center of slot at "medium" or normal driving position Valve *A* is nearly closed and valve *B* is partly closed, thus restricting flow of hot gases through riser jacket. As throttle is opened, valve *A* will open quickly

This setting of control lever may be used when engine is thoroughly warmed up Lower position should not be used except in extremely hot weather

Set the air screw so that the end is flush with the end of the ratchet set spring. Turn the gasoline-adjustment screw to the right very carefully, so as not to injure the needle point, until the valve is closed against its seat. Then turn the adjustment to the left approximately one complete turn, which will bring the notch in the disk handle directly below the guide post above it. This notch is placed in the disk at the factory and indicates the setting for the best power and economy.

Start the engine in the usual manner and place the heat-control lever on No. 2. After the engine has thoroughly warmed up, push the choke

button in all the way and set the air screw for good idling. It may be necessary to turn the screw to the left for more air or to the right for less air to obtain smooth, even running.

If the engine idles too fast with the throttle closed, the latter may be adjusted by means of the throttle-lever adjusting screw.

Rich Mixture.—An over-rich mixture will cause the engine to fluctuate and "roll" at an idle speed, and to "lope" at intermediate speeds.

To remedy this condition, cut down the fuel or increase the air, or both, and keep the heat-control lever at the center mark in the slot and at a lower position only when the weather is extremely hot.

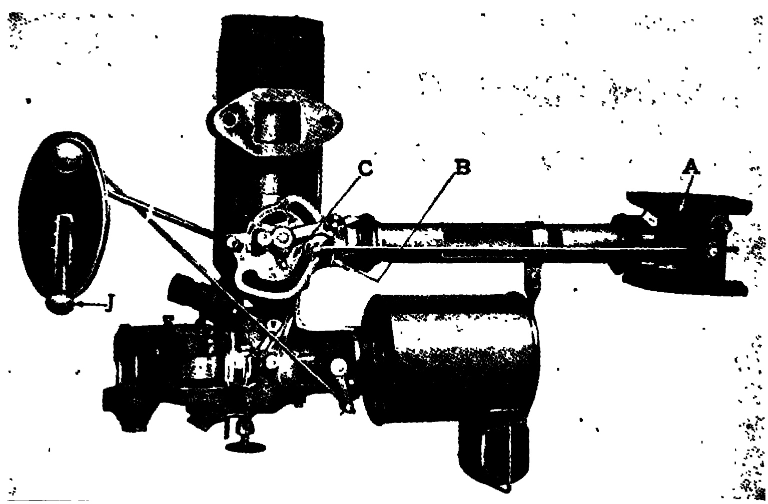


Fig. 1e.—Marvel Carburetor Showing Heat Lever at "Off" Position.

Lean Mixture.—Generally, the best adjustment is obtained with the fuel and air valves set as previously described. It must be remembered that too lean a mixture (as well as an over-rich mixture) causes overheating and a loss of power and is not as economical as an adjustment which provides just the proper proportion of gasoline and air.

The Schebler Carburetor.—The Schebler Model S Carburetor, shown in Fig. 1*f*, is of the expanding type of construction, having variable air passages, while the fuel is automatically controlled in proportion.

The carburetor is designed to give maximum power and maximum economy with the same adjustment.

There are two air inlets on the carburetor. The fixed air opening is through the venturi at the base of the carburetor and is quite small. fur-

nishing only enough air to enable the engine to idle. The auxiliary air valve at the top of the carburetor, which is closed for idling, opens wide for full power. The auxiliary air valve is connected to the needle valve through a proportioning lever. As the auxiliary air valve opens, the fuel needle is lifted proportionately. With this construction the flow of fuel is maintained in exactly the proper proportion to the flow of air.

A sudden enrichment of the mixture is necessary to quick engine acceleration and additional power for maximum speed. The carburetor is equipped with an accelerating pump for this purpose. When the throttle is opened suddenly, the piston of the accelerating pump is raised, thus lifting fuel into the upper chamber. This small amount of fuel flows through the metering nozzle leading directly into the venturi tube at the point where the rush of air is at its height, and the mixture is instantly enriched to proportions for maximum power.

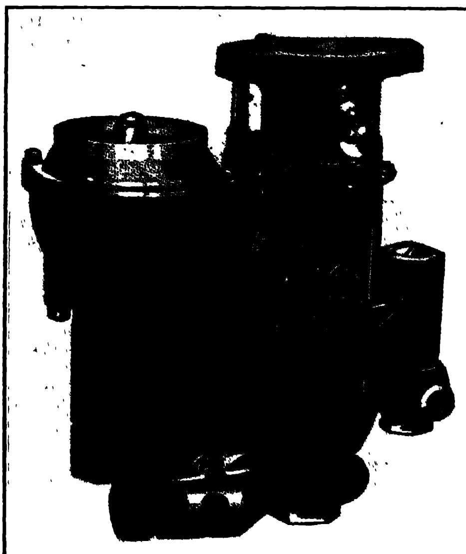


FIG. 1*f*.—The Schebler Carburetor.

While the car is being driven at medium speed with the throttle partly open, the mixture is regulated for maximum economy. When the throttle is open wide, the cam on the throttle shaft strikes the lever to which the choker wire is connected and gives an additional lift to the fuel needle, increasing the proportion of fuel to air.

Idle Adjustment.—Turning the idle adjusting screw *A* (Fig. 1*g*), to the right clockwise gives a leaner mixture. Turning it to the left counter-clockwise gives a richer mixture. This adjustment is not sensitive, and can be turned from three to ten notches without seriously affecting the idling of the engine.

The idle adjustment should be so set that depressing the air valve slightly ($\frac{1}{32}$ to $\frac{1}{16}$ inch) will cause the engine to miss. If the mixture is too lean, the engine will stop when the air valve is depressed slightly. If the mixture is too rich, the engine will speed up slightly when the air valve is depressed. The valve will have to be depressed considerably before the engine misses fire or stops.

If the idle adjustment is turned too far to the right, the air valve will not seat, since the needle is shut off too far. To correct this condition, turn the idle adjustment to the left until the air valve seats, and adjust again.

Range Adjustment.—This adjustment is effective *only* in the driving range, at speeds from 20 to 40 miles an hour, and it *does not* affect acceleration or hill climbing. The adjustment as made at the factory will usually be found the best, and it is seldom if ever necessary to change it. However, if an adjustment is desired, the following instructions should be followed:

Turning the range-adjusting screw *B* to the left gives the driving range a leaner mixture. Turning it to the right gives a richer mixture.

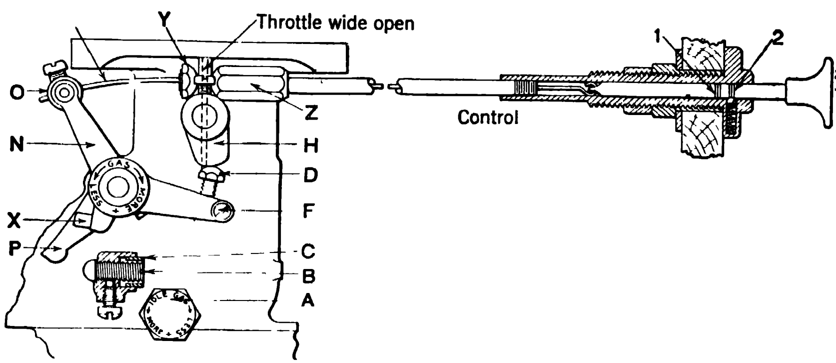


FIG. 1*g*.—Schebler Carburetor Adjustments.

To obtain the original factory setting, the end of the range-adjustment screw *B* should be set flush with the range-adjustment screw bushing *C*.

If the range adjustment is changed, it is very important to readjust the idle mixture.

High-speed Adjustment.—This adjustment is effective *only* at the wide-open throttle position and ordinarily need not be changed. It is very sensitive to one turn in either direction. For the best results in changing this adjustment, the manufacturers recommend that it be changed one complete turn in either direction and tried on a hill after each change.

The adjusting cam screw *D* should be turned to the left to give a richer mixture, and to the right for a leaner mixture. With the throttle wide open, adjust the cam tappet screw *D* until there is $\frac{7}{32}$ to $\frac{1}{4}$ inch space between the dash control lever *P* and the end of the range screw *B*.

Choker.—In starting a cold engine the carburetor choker should be pulled out to the first notch. This operation raises the position of the

needle valve and automatically supplies a very rich mixture to the engine, thus enabling the engine to start easily. The choker should be pushed in just as soon as the engine is warmed sufficiently to run without spitting back into the carburetor. Excessive use of the choker should be avoided as this is likely to cause crank-case dilution. The second notch on the choker should never be used unless it it absolutely necessary, as this position produces an exceedingly rich mixture.

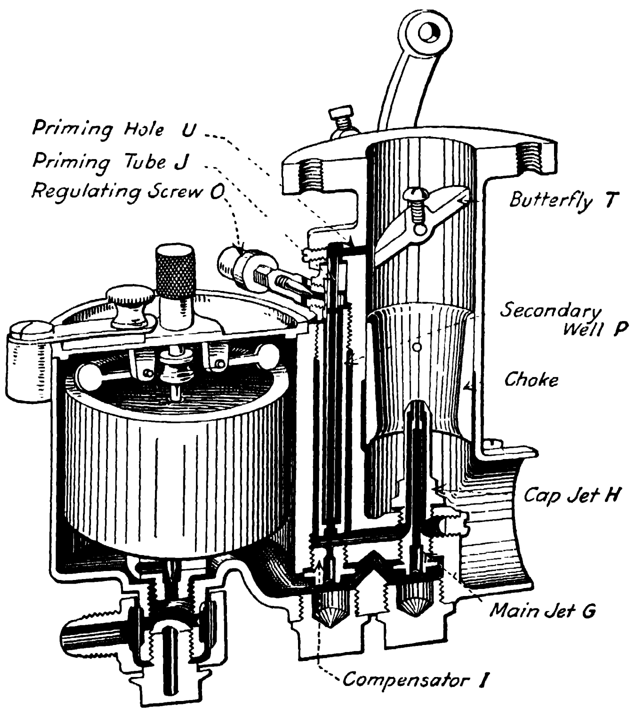


FIG. 1*h*.—Zenith Carburetor.

Adjusting the Zenith.—In the Zenith Carburetor (Fig. 1*h*) the quality of the mixture is fixed, once for all, by the choosing of the three variables: Choke tube, main jet, and compensator, as indicated in the following description.

The size number of these three parts constitutes what is called the "setting." The size number is stamped on the end of each part. When cars are regularly equipped at the factory with the Zenith Carburetor it is seldom necessary to change the "factory setting." These settings have, in every such case, been determined by experts after exhaustive tests, and as there are no moving parts in the Zenith in any way affecting the mix-

ture, it is reasonable to assume that any trouble that may arise can be caused only by dirt and water in the carburetor. When adjustments are believed to be necessary the car should be taken to a service station which specializes in carburetors of this type. The screw *O* (Fig. 1*h*) controls the amount of gas necessary for proper operation of the engine when the throttle is closed.

Questions.

1. What precautions should be used to prevent fire when adjusting a carburetor?
2. Why is it necessary to place the carburetor lower than the gasoline supply tank where a gravity feed is used?
3. What is a gravity feed?
4. What is a force feed?
5. How is the size of a carburetor determined?
6. What is the specific gravity of gasoline?
7. What other fuels are used in gas engines?
8. What changes are necessary for these fuels?
9. What are some of the objections to their use?
10. What is the approximate ratio by volume of gas vapor to air in a satisfactory mixture? By weight?
11. What are some of the special vaporizing devices installed on automobile engines?
12. What were the early forms of carburetors used on stationary engines called?
13. What are the functions of a carburetor?
14. What different methods are used to govern the supply of gas in a carburetor?
15. How are carburetors primed?
16. What are the advantages of spray carburetors over the Zenith type?
17. What is an indication of too rich a mixture at low speed?
18. What is the effect if the mixture is set too lean for low speed?
19. What is the indication of too lean a mixture at high speed?
20. What is an indication of too rich a mixture at high speed?

Job No. 2

INSTALLING CARBURETORS

References.—Part Two, p. 477.

Operations Necessary to Perform the Job.

1. Inspect carburetor for correct size.
2. Clean surface of flanges.

3. Fit gasket.
4. Attach carburetor.
5. Attach fuel feed line.
6. Connect throttle control.
7. Connect dash control or choking device.
8. Connect heating controls.
9. Adjust carburetor.

Description of Operations.

It is important to determine the correct size of the carburetor before attempting to make an installation. To obtain the size, measure the opening on the flange of the carburetor. This opening should be the same size as the opening on the intake manifold or the cylinder block. The size of the opening varies according to the type of carburetor that is to be installed. A vertical type is generally connected to the manifold (Fig. 1*d*), and a horizontal type is usually connected to the cylinder block (Fig. 2*a*). Always clean and level the surface of both flanges with emery cloth or a smooth file.

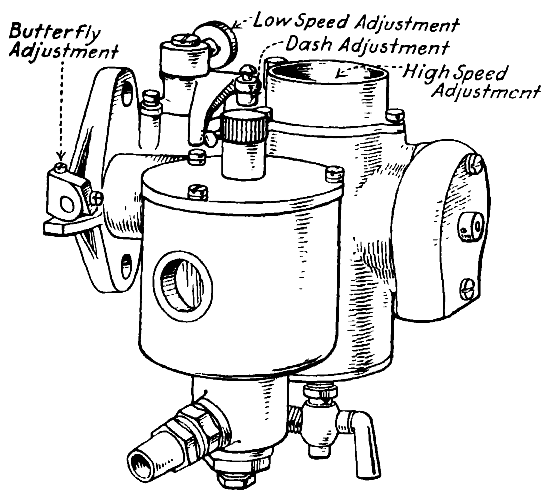


FIG. 2*a*.—Carburetor Having a Side Flange for Connection to Engine Block.

A gasket should be cut from suitable gasket material, such as heavy blotting paper, if a prepared gasket is not already available. To cut a gasket, lay the material on either one of the flanges, tap it with a hammer to get the impression, and cut the material accordingly. The gasket should be shellacked to insure an air-tight connection. Good gasket material, well fitted, may be used without shellac. The carburetor should now be attached with the float chamber facing either to the front or to the rear, as may be necessary, so that the adjustments will be on the outside.

Where a gravity feed is used, the carburetor must be placed low enough to insure a flow on hills when the gasoline is low in the tank. After attaching the carburetor, connect the feed pipe, turn on the gaso-

line, and inspect the fuel line for leaks. If the connections are satisfactory, connect the throttle control rods, testing them for correct length by operating the throttle lever on top of the steering column. Now connect the dash control to the air-choke valve or priming device on the carburetor and test again for correct operation. The engine should now be started and the carburetor adjusted as directed in Job No. 1.

Whenever new types of carburetors need adjustment, instruction handbooks furnished by the manufacturers should be consulted for specific directions.

The modern carburetor has been constructed so as to perform its duty when using low-grade fuels and under variable conditions; therefore, in most types, delicate adjustments must be made for satisfactory operations. When once adjusted it should not be changed unless the trouble is definitely located and a new adjustment is necessary.

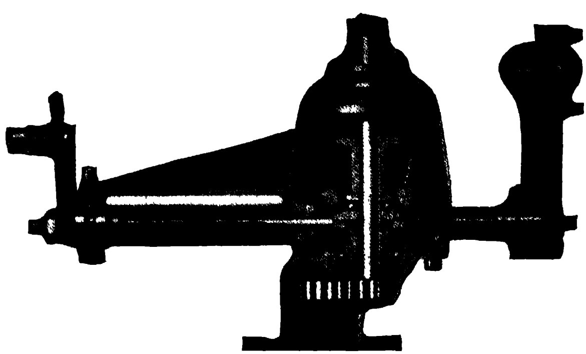


Fig. 2b.—Fuel Governor. (Sectional View.)

The governing device shown in Fig. 2b is used on trucks and is designed to give an automatic control at all times either of the vehicle speed or of the engine speed. The governor does not permit the engine speed to exceed a set maximum. Speed is very destructive to trucks and solid tires.

Because of the presence of carbon monoxide, a deadly poisonous gas, in the exhaust of the engine, never operate the engine for any length of time while the car is in a small, closed garage.

Opening the doors and windows will lessen the danger considerably, but it is safest, if adjustments are being made that require the operation of the engine, to run the car out of doors.

Questions.

1. What are the usual methods of applying heat to aid in the vaporization of the fuel?
2. What is meant by a $1\frac{1}{4}$-inch carburetor?
3. On what vehicles are fuel governors used?
4. How can fuel lines be tested?

5. What are the indications of a leak in a metal float?
6. What are the indications of trouble with a cork float?
7. How deep should the gasoline be in the float chamber?
8. If the float valve leaks, what precautions should be taken when the car is not in use?
9. What effect will a leak in the manifold gasket have on the engine?
10. What effect will leaky valve stems have on the operation of the engine?
11. How can a weak exhaust-valve spring affect the operation of the engine?
12. Is it possible to get smooth running with unequal compression in the cylinders?
13. How will the spark gap affect the operation of the engine?
14. Which mixture will give more power: a little too rich or a little too lean?
15. Which will be more economical and cause less trouble?
16. On modern cars, what device is used to keep the engine running when starting in cold weather?
17. What should be done as the engine warms up?

Job No. 3.

INSTALLING A VACUUM TANK

References.—Part Two, p. 486.

Operations Necessary to Perform the Job.

1. Fasten tank firmly on engine or dash, keeping it away from the exhaust manifold, and with the bottom of the tank above the level of the carburetor and gasoline supply tank.
2. Measure suction coupling on top of the tank, for size of coupling and tubing needed to connect suction line to intake manifold.
3. Drill hole in manifold and tap according to pipe measurements.
4. Cut tubing to correct length.
5. Attach couplings to tubing and make connections.
6. Measure gravity-feed coupling at bottom of tank.
7. Measure carburetor coupling for size of material needed.
8. Cut gravity-feed line tubing to correct length.
9. Attach fittings and make connections.
10. Connect fuel pipe leading from gasoline supply tank to suction coupling on top of vacuum tank.
11. Prime tank with gasoline.
12. Inspect for air or gas leaks at couplings.
13. Start engine, test tank operation, and adjust carburetor if necessary.

Description of Operations.

The Vacuum Gasoline System employs a small tank, installed under the hood. This tank is connected by brass or copper tubing to the

intake manifold, also to the gasoline supply tank, and to the carburetor. Every engine draws its supply of gasoline through the carburetor by reason

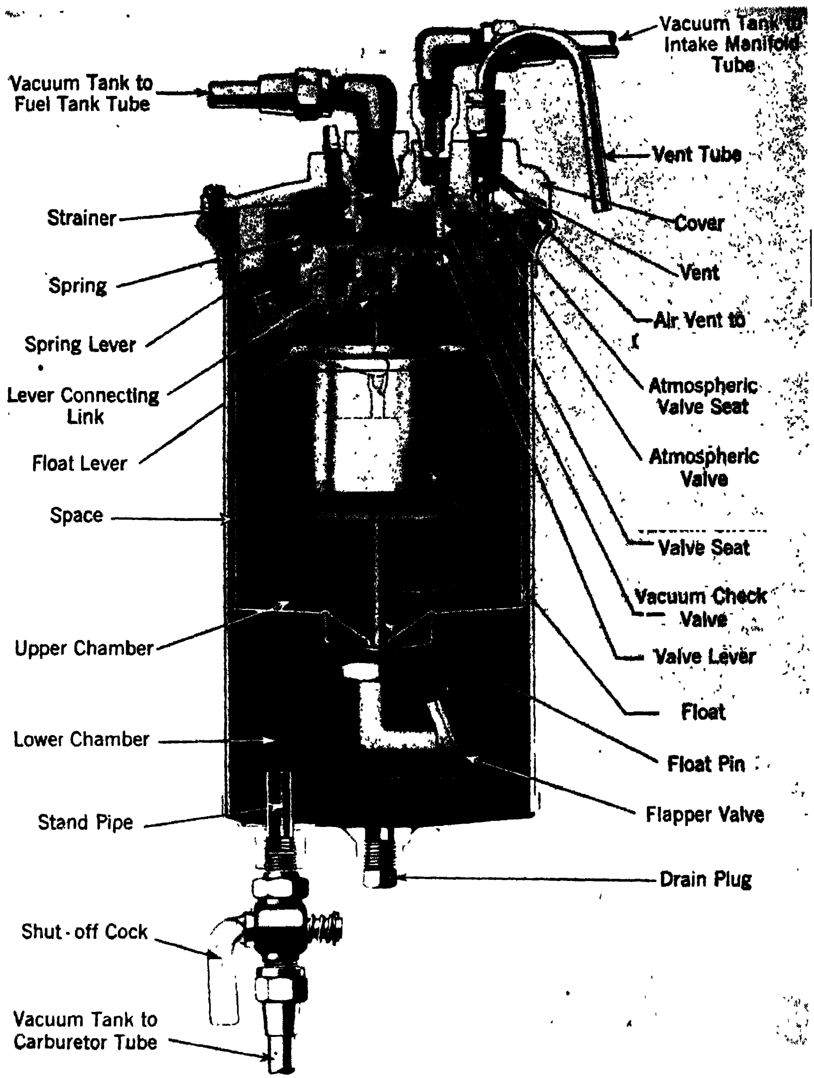


FIG. 3*a*.—Stewart Vacuum Tank.

of the pumping action of the pistons. It is this same pumping action which draws gasoline from the main supply tank into the vacuum tank.

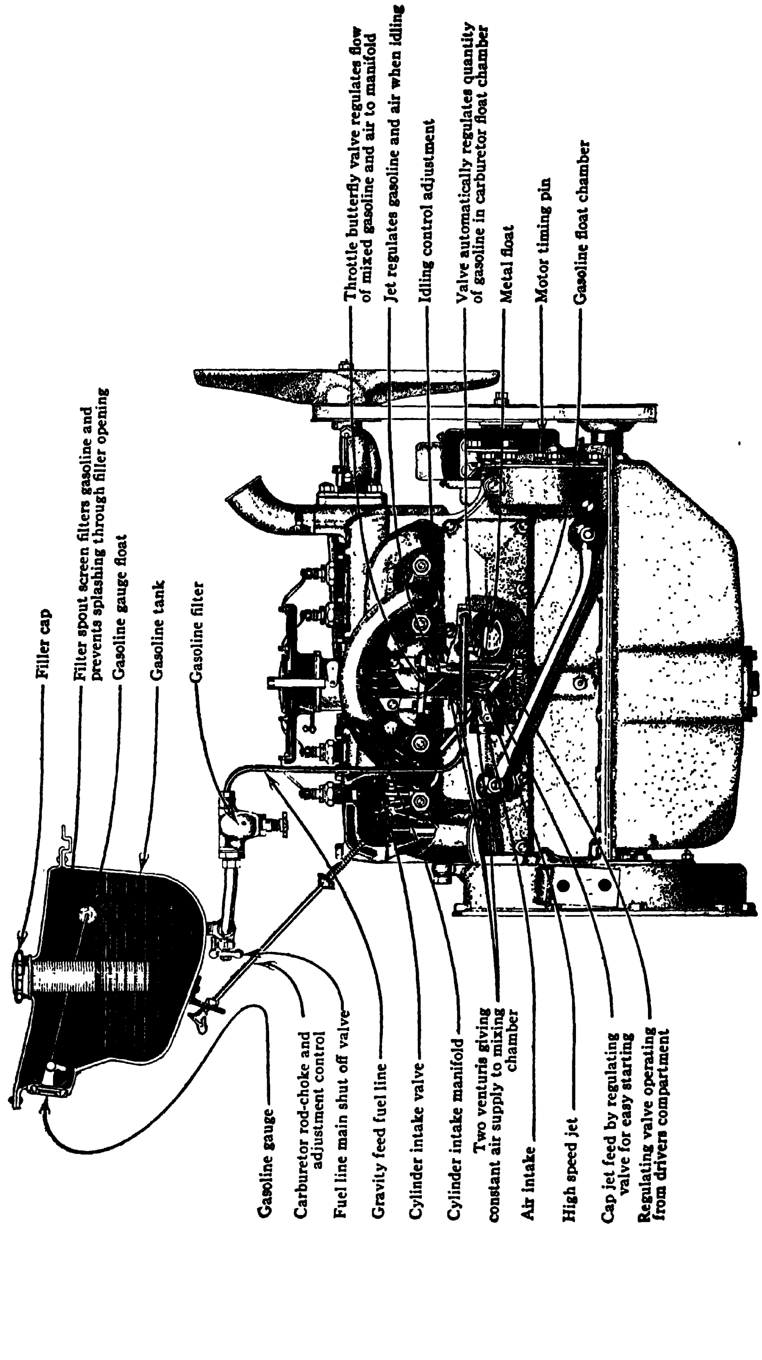


FIG. 3b.—The Gasoline System. (Model A Ford.)

The Stewart Vacuum Gasoline Tank (Fig. 3*a*) is described on page 486 of Part Two.

When installing a vacuum tank, fasten it firmly on the engine or dash well away from the exhaust manifold so as to avoid all danger of fire from gasoline leaking on the exhaust manifold. It is necessary to keep the bottom of the tank above the level of the carburetor to insure a flow of gas when climbing hills, since gasoline is fed by gravity from the lower chamber of the vacuum tank to the carburetor. Make measurements of the suction coupling on the top of the tank (Fig. 3*a*), for the size of a coupling and of the tubing needed to connect the suction line to the intake manifold. Remove the carburetor, drill a hold in the manifold, and tap to suit the fitting to be used. Replace the carburetor, cut the tubing to a correct length, attach the couplings to the tubing, and connect up the tank to the manifold.

Measure the gravity-feed coupling at the bottom of the tank and the carburetor fuel line coupling for the size of the opening and for the material needed. Cut the tubing to the correct length, attach the couplings, and make the connections. Now connect the feed pipe leading from the gasoline supply tank to the fuel-tank tube coupling on the top of the vacuum tank. Prime the tank with gasoline through the priming plug and inspect the lines for air or gas leaks at the couplings. Start the engine and test the tank as to operation and for gas leaks, and adjust the carburetor if necessary.

Questions.

1. What is the purpose of a vacuum tank?
2. Do vacuum tanks save fuel?
3. Where carburetors are attached directly to the engine blocks, how are vacuum tanks installed?
4. What measurements are taken to determine pipe sizes?
5. What care should be taken to protect the car from fire?
6. Why must the tank be located above the carburetor?
7. Are adjustments necessary?
8. Why should the tank be cleaned after several months?
9. What is the need for the drain plug (Fig. 3*a*)?
10. Is it necessary that the main gasoline line be air-tight? Should the tank have an air vent?
11. What is the use of the standpipe in Fig. 3*a*?

Job No. 4

OVERHAULING A VACUUM TANK

References.—Part Two, p. 486.

Operations Necessary to Perform the Job.

1. Examine air-vent tube for dirt or obstruction.
2. Inspect couplings for air and gas leaks.
3. Inspect gasoline filter screen for dirt or obstruction.
4. Remove the top of the tank and lift out vacuum chamber.
5. Examine for leaky gaskets and leaky or defective float.
6. Inspect valve mechanism as to working condition.
7. Make necessary repairs or replacements.
8. Reassemble tank.
9. Prime tank with gasoline.
10. Start engine and test tank operation.
11. Adjust carburetor if necessary.

Names of Parts to be Reviewed before Performing the Job.

Vacuum-valve stem, atmospheric stem, float lever, spring lever, valve-stem lever, connecting-link pin, vacuum-check valve, float-assembly, top cover assembly, top inner shell assembly, top-cover gasket, outside-shell assembly.

Description of Operations.

Some of the common symptoms of fuel-system troubles, which are attributed to the vacuum tank, are (1) frequent emptying of the carburetor float chamber when the supply tank, gasoline lines, tank filler cap vent, screens, filter, vacuum vent pipe, suction pipe, carburetor float, and float valve are found to be in proper condition; (2) emptying of the carburetor float chamber while the engine is running and then refilling as soon as the engine stops; (3) excessive delivery of raw fuel through the suction pipe into the manifold, causing the engine to "gallop" and exhaust black clouds of smoke although the carburetor adjustments are correct.

Figure 4*a* illustrates a simple vacuum-tank tester which may be used to show whether the tank is functioning properly. To use the tester, disconnect the line leading from the main fuel tank at the vacuum tank. Connect tube *B* of the tester to the end of the fuel line and tube *A* of the

tester to the vacuum tank, with rubber tubing. Start the engine and run it until gas is drawn into the tester and into the vacuum tank. If the engine runs until the vacuum is empty and no gas is drawn through the bottle, it is evident that the trouble is in the vacuum. To ascertain whether the engine is drawing raw gas through the manifold suction pipe, disconnect the suction pipe, insert the tester in between, and connect tube *B* of the tester to the manifold. If gas is drawn into the bottle when the engine is running, the vacuum is at fault.

Most vacuum-type windshield cleaners are connected to the vacuum-tank suction pipe at the top of the vacuum tank. Before dismantling the fuel system, inspect the windshield hose to ascertain whether it is chafed or broken or has a leak of any kind. A leak in this rubber tube will often affect the operation of the vacuum tank.

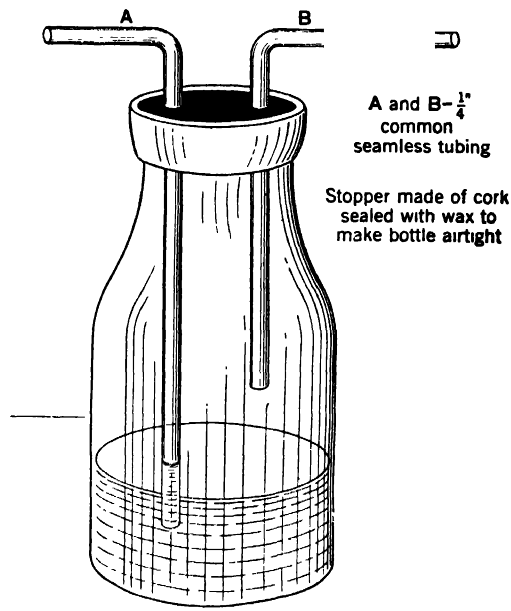


FIG. 4*a*.—Simple Vacuum-tank Tester.

If gasoline leaks from the system, except from the vent tube, it can only do so from one of the following causes:

A. A leak in the outer wall of the tank may have occurred. Soldering up the hole will eliminate this trouble.

B. The carburetor connection in the bottom of the tank may be loose. In this case the nut should be tightened.

C. There may be a leak in the tubing. Where the flow of gas does not reach the carburetor the trouble may be due to other causes than the vacuum system. Do not blame the vacuum system until you are sure that the fault does not lie elsewhere. After flooding the carburetor, or "Tickling the Carburetor" as it is commonly called, if gasoline runs out of the carburetor float chamber, it is evident that the vacuum feed is performing its work of feeding the gasoline to the carburetor.

Another test is to remove the top and take out the inner vacuum tank, leaving only the outer shell. If this shell is filled with gasoline

and the engine still refuses to run properly, then the fault clearly lies elsewhere and not with the vacuum system—unless there is a stoppage in the fuel line leading to the carburetor.

When removing the top of the tank, take out the screws, run the blade of a knife carefully around the top, between the cover and the body of the tank, so as to separate the gasket without damaging it. The gasket is shellacked to make an air-tight joint. If a faulty feed is traced to the vacuum system, one of the following conditions may be the cause.

A. The float (see *G*, Fig. 3*a*) which should be air-tight may have developed a leak; thus filling up the float with gasoline and making it too heavy to rise sufficiently to close the vacuum valve. This allows gasoline, which in turn will choke down the engine, to be drawn into the manifold. Correct operation depends upon the float being air-tight.

To repair the float remove the top of the tank (to which the float is attached) as directed. Dip the float into a pan of hot water in order to find out definitely where the leak is. Bubbles will be seen at the points where a leak exists. Mark the spots. Next, punch two small holes, one in the top and the other in the bottom of the float, to permit discharge of any gasoline which may have accumulated. After the gasoline is entirely drained, solder up these holes and the hole at the leak. Test the float by dipping it again in hot water. If no more bubbles are seen, the float is now air-tight.

In soldering the float be careful not to use more solder than is required. Any unnecessary amount of solder will make the float too heavy.

In taking out the float and repairing it, do not bend the float guide rod. If the rod is bent it will strike against the guide and retard the float, thus producing the same effect as a leaky float. Examine the surface of the rod to remove any roughness which may prevent the float from operating.

To overcome, temporarily, trouble due to a leaky float, remove the priming plug, usually a $\frac{1}{8}$ or a $\frac{1}{4}$-inch pipe plug, located on the vacuum-tank cover. In some cases the suction of the engine is sufficient to draw gasoline into the tank even with this plug open, but not enough to continue to draw it into the manifold. If this arrangement is not satisfactory, replace the plug *W* with the engine running. After running the engine until the tank is full, remove the plug *W* until the gasoline gives out. Continue to repeat these operations until you arrive at a repair station or garage, where the leaky float can be repaired.

B. The flapper valve may be out of commission:

A small particle of dirt getting under the flapper valve (Fig. 3*a*) might prevent it from seating and thereby render the tank inoperative.

In order to determine whether or not the flapper valve is out of commission, first plug up the air vent; then detach the tube running from the bottom of the tank to the carburetor. Start the engine and apply a finger to this opening. If the suction is felt continuously it is evident that there is a leak in the connection between the tank and the main gasoline supply, or that the flapper valve is being held off its seat and is letting air into the tank, instead of gasoline.

In many cases this troublesome condition of the flapper valve can be remedied by merely tapping the side of the tank, thus shaking loose the particle of dirt which has clogged the valve. If this does not prove effective, remove the tank cover, as described on a previous page, and lift out the inner tank. The flapper valve will be found screwed into the bottom of this inner tank.

C. The manifold connection (Fig. 3*a*) may be loose, allowing air to be drawn into the manifold.

D. The tubing may be stopped up.

E. The gasoline strainer is a screen located in the line from the gasoline tank. This screen collects all foreign substances that might get in the rear tank and be carried through to the carburetor and clog up the filter screen. If the tank fails to work, it may be that this screen is clogged, preventing gasoline from getting into the tank. The screen may be easily cleaned by unfastening the connection at the elbow. This cleaning should be done every three weeks. If the tank should ever fail to operate, examine the strainer first.

The vacuum feed should show the same rate of gasoline consumption as a gravity feed, and a saving over pressure feed. If such a condition does not exist, perhaps the cause is one of the following:

a. The carburetor may need adjustment.

b. The vent tube may overflow.

c. There may be a leak in the tank or tubing.

d. If the engine speeds up when the vacuum tank is drawing gasoline from the main supply, it shows that either the carburetor mixture is too rich, or the connections are so loose that it is drawing air into the manifold. There should be no perceptible change in the engine speed when the tank is operating.

e. Carburetor trouble cannot be attributed to a vacuum system. If gasoline is delivered to the carburetor, the vacuum feed has done its work.

f. If the carburetor pops and spits, carburetor adjustment is needed.

To fill the tank, should it ever become entirely empty, close the engine throttle and turn the engine over a few revolutions. This will create sufficient vacuum in the tank to fill it. If the tank has been

allowed to stand empty for a considerable time and it does not easily fill when the engine is turned over, the trouble may be due to dirt or sediment being under the flapper valve *H*, or, perhaps, the valves are dry. Removing the plug *W* in the top and pouring a little gasoline into the tank will wash the dirt from this valve, and also wet the valves and cause the tank to work immediately. The flapper valve sometimes gets a black carbon pitting on it, which may tend to prevent it from being held tight on its seat. In this case the valve should be scraped with a knife.

Questions.

1. How is the vacuum chamber removed?
2. Does the air-vent tube lead into the gravity or vacuum chamber?
3. Where are the suction and atmosphere valves located?
4. What operates the suction and atmosphere valves?
5. If the tubing is badly damaged, would it be advisable to repair the old tubing or to replace it with a new one?
6. How can you make sure that there is fuel in the cylinders?
7. If the engine, after it has been primed, runs a few revolutions, and then stops, what is the probable cause of the trouble?
8. How can the driver determine whether there is a flow of fuel to the carburetor?
9. If the fuel does not run into the float chamber properly, when the float needle or cover of the float chamber is lifted, what is the probable cause of the trouble?
10. Where might a trap or filter be located?
11. Would it be advisable to do anything to the trap before the supply of fuel in the tank is investigated?
12. If the engine will not start when the cylinders have been primed, what may be the trouble?
13. What test can a driver easily make to determine whether a spark is being supplied to the plug?
14. Is it necessary to remove the plugs to make the above test?

Job No. 5.

STARTING ENGINE

References.—Part Two, pp. 390-92.

Operations Necessary to Perform the Job.

1. Set emergency brake.
2. Place gear-shifting lever in neutral position.
3. Retard spark.

4. Open throttle part way.
5. Set carburetor dash-control lever or choke button.
6. Turn ignition switch to starting position and crank the engine with starting motor or by hand.
7. After engine is started and running, advance spark about one-third of the range of the quadrant.
8. Run engine a few minutes at a normal speed to warm it up.
9. Set dash-control lever or choke button to running position.
10. Set spark and throttle lever so that engine runs evenly and steadily at idling speed, and examine gasoline supply in main tank.

Description of Operations.

When starting the engine the emergency brakes should be set and the gear-shift lever should be placed in the " neutral " or disengaged position.

With the spark retarded, open the throttle part way and set the carburetor dash-control or choke-button lever to its starting position. Turn the ignition switch to its starting or " on " position and crank the engine with the starting motor or hand crank. After the engine is started and running, advance the spark about one-third of the range of the quadrant. Run the engine a few minutes at a normal speed until it becomes warm, and set the dash-control lever to its running position. Move the spark and throttle-control levers so that the engine runs evenly and steadily at its idling speed, and examine the gasoline supply in the main tank. Inspect the tires, and examine the oil supply and the water in the radiator. Observe the ammeter and oil gauge carefully, to see that the generator and oil pump are performing properly.

These precautions should be taken whenever a trip of any length is planned or when one is likely to be far from a filling station.

It frequently happens that when driving in a very crowded street the noise of the traffic prevents the driver from hearing whether his engine is running or not. As a result, the starting pedal is pressed down with the intention of starting the engine. The resulting screeching sound is an indication of having done some damage to the starting gears.

To safeguard against damaging the gears in this way, it is a good plan to get into the habit of either pressing down on the foot accelerator or advancing the hand throttle so as to determine whether the engine is running. The dash ammeter, which is connected in series with a battery ignition system, will indicate whether the engine is stalled or running.

When the engine is stopped or stalled, do not leave the ignition switch on. This may permit the battery to discharge through the coil, and in some cases through the generator winding.

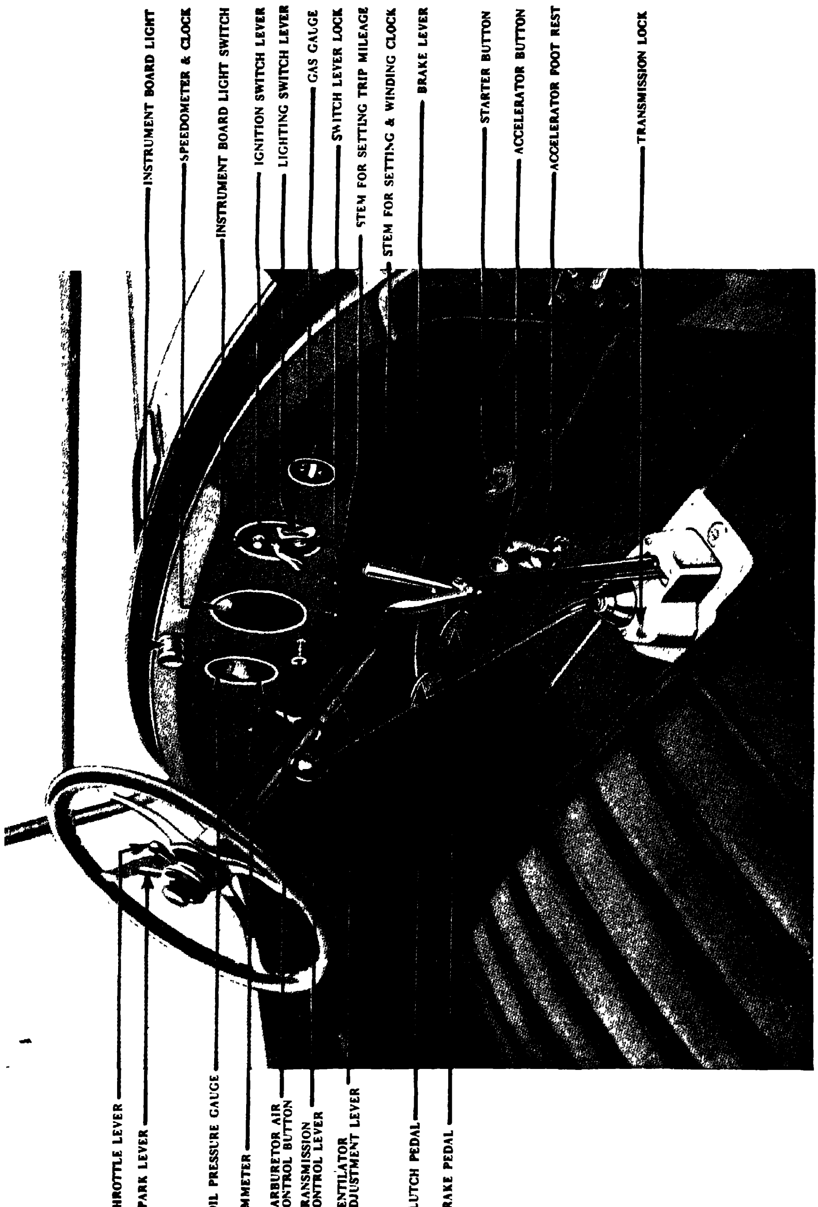


FIG. 5*a*.—Driver's Compartment. (Peerless.)

When engaging the starter gears, it sometimes happens with sliding gear clutches that the teeth do not mesh readily. Do not force the starter pedal but allow it to come back a little and try again. By this time the gears will have changed their positions so as to allow the teeth to mesh properly.

Questions.

1. What three conditions are necessary for the engine to start and to run properly?
2. Why does the engine start more easily in summer than in winter?
3. If the engine, after it has been primed, runs a few revolutions, and then stops, what is the probable cause of the trouble?
4. How can the driver determine whether there is a flow of gasoline into the carburetor?
5. What test can be made to determine whether a spark is supplied at the spark plugs?
6. How may injuries be avoided when cranking by hand?
7. Why will an engine not pull as soon as it is started in cold weather?
8. Will damage result if the starting pedal is held down after the engine starts?
9. Why should the emergency brakes be set when starting?
10. What should be the position of the spark lever when starting? When running? Why?

Job No. 6

ENGINE TROUBLES—ENGINE HARD TO START

References.—Part Two, pp. 390-2.

Operations Necessary to Perform the Job.

1. Use starting crank and test engine for stiffness.
2. Test spark at the spark plugs, try carburetor choke and primer, and examine gas supply.
3. If spark is weak or none is obtained, and a battery system is used, test battery for discharged or defective cells.
4. Recharge or replace as necessary.
5. Examine wire assembly for loose or broken connections, defective insulation, or incorrect wiring.
6. If wiring is in good condition, inspect condition of interrupter and distributor for short or open circuit, pitted points, incorrect adjustment of points, weak or broken interrupter-arm spring, defective rotor or brush.

7. If trouble has not yet been located, test ignition coil for short circuit, open circuit, or broken-down condenser.
8. If high-tension magneto is used, examine coupling for backlash and test condition of magneto.
9. After correct spark is obtained, if engine still starts hard, examine carburetor for gasoline by flooding float chamber or by using drain cock.
10. If no fuel is found in carburetor, inspect tank for supply and examine gasoline feed pipe for obstruction.
11. If trouble has not yet been located and there is gasoline in the carburetor, examine carburetor adjustments for correct mixture.
12. If engine is still hard to start, test compression; if poor, prime cylinders with cylinder oil, crank engine a few turns, and then prime cylinders with gasoline.

Names of Materials, Tools, and Special Terms to be Reviewed before Performing the Job.

Materials.—Gasoline, cylinder oil.

Tools.—Voltmeter, point file, flat carborundum stone, magneto wrench, extra condenser for testing purposes.

Special.—"Open circuit," "short circuit," "broken-down condenser," pitted points, defective insulation.

Description of Operations.

Where a mechanically free gas engine is hard to start, all sources of trouble may be located in one of three conditions which must exist before the engine will run. These conditions are as follows:

1. A suitable mixture of fuel and air in the cylinders. This mixture varies, with gasoline of from 5 to 15 parts of air by volume to 1 part of gasoline vapor, in order to be combustible.
2. The combustible mixture must be under compression.
3. A hot spark must be produced in the compressed mixture at the right time.

To start the engine, test it for stiffness with the starting crank. Crank the engine slowly to feel whether there is some movable part of the engine dragging, binding, or stuck. These conditions are generally caused by flooding the cylinders with gasoline when priming the engine. The gasoline removes the lubricant from the cylinder walls and pistons, causing them to drag through increased friction. It also causes poor compression and dilutes the oil in the crank case if too much gas is used. This dilution causes the bearings to bind.

If the engine cranks freely, test the spark at the spark plugs. If the spark is weak or if none is obtained and a battery system is used, test the battery for discharged or defective cells, and recharge or replace it as may be necessary. The battery must be in good condition, if the starter cranks the engine normally.

Examine the wire assembly for a loose or broken connection, defective insulation, or incorrect wiring. If no trouble is found in the wiring, inspect the condition of the interrupter and the distributor for a "short" or open circuit, pitted points, incorrect adjustment of the points, a weak or broken interrupter-arm spring, defective rotor or brush. If the trouble has not yet been located, the ignition coil should be tested for a "short" or open circuit and for a broken-down condenser.

Where a high-tension magneto is used, the trouble may be in the coupling and may be due to backlash. If after a correct spark has been obtained the engine does not start, attention should be directed to the carburetor for trouble due to gasoline flooding the float chamber. If no fuel is found in the carburetor, the gas tank should be examined for a supply. If a supply is found, examine the gasoline feed pipes for possible obstructions. If the trouble has not yet been located, and there is gasoline in the carburetor, make adjustments for a correct mixture and test the compression. If it is poor, prime the cylinders with cylinder oil, crank the engine a few turns, and prime the cylinders with gasoline. An engine that will start readily after the cylinders have been primed with gasoline indicates that the choke or primer is not performing properly. With the above parts in a satisfactory condition, there should be a proper mixture of fuel, good compression, and a satisfactory spark, and the engine should start.

Questions.

1. How is a battery tested for discharged or defective cells?
2. How is an ignition coil tested?
3. How is the compression tested?
4. What is a filter trap, and where is it located?
5. Can the firing of a gas engine be compared to the firing of a loaded gun?
6. Are there different grades of gunpowder?
7. What difference is noted, in the operation of an engine, between using a weak and a rich mixture?
8. How is the correct mixture obtained?
9. What devices are used to vaporize the gasoline?
10. Will gasoline burn without air or some other source from which oxygen can be obtained?

11. If a car takes fire as a result of a gas leak, what are the best ways to extinguish the fire?
12. What causes dirty spark plugs?
13. Why is it sometimes necessary to make a new adjustment of spark-plug points?
14. What should a fully charged battery test?
15. Will better results be obtained if a lighter grade of gasoline is used in the winter season?

Job No. 7

ENGINE TROUBLES ENGINE STALLS

References.—Part Two, pp. 390-2.

Operations Necessary to Perform the Job.

1. Examine carburetor and fuel tank for gasoline supply.
2. Examine feed pipe for obstruction.
3. Inspect filter trap and filter screen for water or sediment and examine condition of carburetor.
4. With a supply of gasoline and the carburetor in good condition, try to start engine again.
5. If trouble is not overcome and engine still stalls, examine wire assembly for loose or broken connection.
6. Test ignition system for a spark and examine condition.
7. If wires are in a satisfactory condition and a vacuum tank is used, examine filter screen and lower chamber of tank for dirt or water.
8. Test air-vent tube for obstruction.
9. Examine valve-tappet adjustment for correct clearance.
10. Examine condition of oil in crank case and change if necessary.
11. If stalling is caused by an overheated engine, allow it to cool before adding water.
12. Start engine and adjust carburetor if needed.

Description of Operations.

It is impossible to set up a list of engine troubles in the order in which they may occur. One of the most valuable assets of a good repairman is the ability to locate or name the trouble. As in the practice of medicine, the most valuable men are those who can diagnose the case and tell some one else what to do to correct the trouble. A good automotive repairman will not begin to disassemble a car without having first located the source of the trouble.

Many repairmen who are able to replace parts and make adjustments are not able to test all sources of trouble in order to locate the one or two troubles immediately responsible for the unsatisfactory condition.

These facts should always be kept in mind when no visible defects can be found, and all known tests should be applied before any parts are removed.

Very frequently the throttle stop screw wears, allowing the butterfly valve to close too tight. Reset the stop screw in this case.

In locating the conditions which may cause an engine to stall, first examine the carburetor and the fuel tank for a gasoline supply, then inspect the feed-line pipe for any obstruction which may stop the flow of gas. If no trouble is found, inspect the filter trap and screen for water or sediment. If these parts are found in a working condition, examine the carburetor and overhaul it if necessary (see Job No. 2).

With a supply of gasoline and the carburetor in a good condition, try to start the engine again. If the trouble is not overcome and the engine still stalls, examine the ignition-wire assembly for a loose or broken connection. When these parts have been inspected, test the ignition system for a secondary spark. If a good spark is produced the engine should be tried again.

Where a vacuum tank is used, the trouble may be due to dirt or water on the filter screen in the lower chamber of the tank. If the filter screen is clear, test the air-vent tube for an obstruction (Job No. 4), and if no cause has yet been found examine the valve tappet adjustments for a correct clearance.

The trouble may be due to a lack of oil in the crank case, which will cause the engine to heat and lose power. When all of these sources of trouble have been tested and the conditions found to be normal, or necessary adjustments have been made, start the engine and make such carburetor adjustments as may be needed.

Questions.

1. What is the average valve clearance?
2. How is the secondary spark tested?
3. What should be the condition of the lubricating oil?
4. What is meant by " wire assembly "?
5. If an engine stalls on account of overheating, is it likely to start after cooling?
6. What effect will too much gas have on a running engine?
7. Why is water, when present in gasoline, always found at the bottom of the tank?

Job No. 8

ENGINE TROUBLES—ENGINE MISSES AT LOW SPEED

References.—Part Two, pp. 390-2.

Operations Necessary to Perform the Job.

1. Start engine and determine missing cylinder or cylinders.
2. Test carburetor adjustment for correct mixture.
3. Test intake manifold for air leaks.
4. Test for weak spark.
5. Examine condition of spark plugs; replace with new plugs if found defective, and set gaps before installing.
6. Stop engine and inspect ignition timing for correct setting or loose connections.
7. Examine interrupter for pitted points and point adjustments.
8. Inspect condition of distributor.
9. Use starting crank and test compression; if poor or uneven make necessary repairs.

Description of Operations.

When the engine misses at low speed, four main conditions may be the cause of the trouble:

1. Poor compression due to a weak exhaust-valve spring, to a leak in the manifold connection, or to valves which need grinding.
2. Ignition out of time.
3. A bad condition of the spark-plug points or a need for adjustment.
4. A weak spark due to pitted interrupter points.

In order to test out these possible causes, start the engine and test the carburetor adjustments for a correct mixture. If the mixture is too rich or too lean, it may be impossible to locate the real cause of missing at low speed.

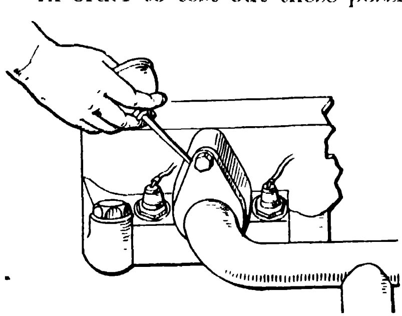


Fig. 8a.—Locating Air Leaks in Intake Manifold.

By using cylinder oil as shown in Fig. 8a, a test can be made for possible leaks in the intake-manifold connections both at the cylinder joints and at the carburetor. If a leak is located, the oil will seal the vent temporarily and the engine should begin to operate satisfactorily. If the trouble is located, it should then be repaired

permanently. If no difference in operation is noted, test the ignition for a weak spark by short-circuiting the spark plugs with a hammer or screw driver. See Fig. 8*b*.

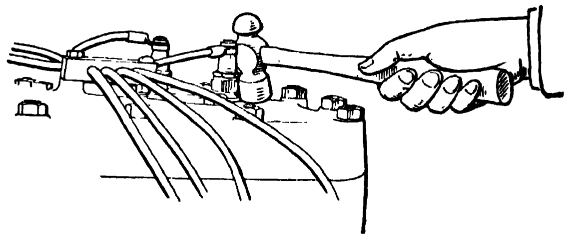


FIG. 8*b*.—Testing the Spark.

If the miss cannot be located, stop the engine and inspect the ignition timing for a correct setting or for loose connections. If the ignition is "out of time," proceed to make the adjustments as in Job No. 3, Chapter III. Where the ignition seems to be in time, take out the spark plugs and examine the points. Dirty or badly burned points should be cleaned or a new plug installed. It may be that the points are out of adjustment. The average setting of these points is from 0.020 to 0.030 inch. The plugs should also be examined for leaky or cracked porcelains. When the spark is satisfactory, examine the interrupter for pitted points and for incorrect adjustment of the points.

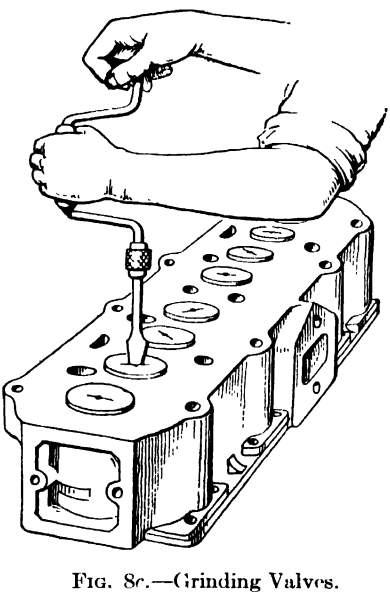


FIG. 8*c*.—Grinding Valves.

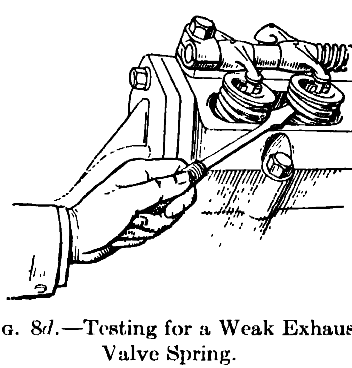


FIG. 8*d*.—Testing for a Weak Exhaust Valve Spring.

The trouble may be due to a dirty or cracked distributor. If it is not located in the distributor, as a last resort test the compression, using the hand crank. When the compression is poor it may be necessary to grind and adjust the valves as in Job No. 1, Chapter II, or to take the engine down and make repairs as in Jobs No. 9 or 10 of the same chapter.

Questions.

1. How are pitted breaker points cleaned?
2. How are spark plugs tested?
3. What are the names of the parts of a cylinder?
4. What kind of gasket material is generally used for intake manifold gaskets?
5. What tools are necessary to adjust contact points?
6. How may one test the spark without removing the wires?
7. How may a weak exhaust-valve spring be the cause of "missing" at low speed and not at high speed?
8. Why will a leak in the manifold cause the engine to miss at low speed? Why not at high speed?
9. Why may bad spark-plug points cause "missing" at low and not at high speed?
10. Why will poor compression cause the engine to miss at low and not at high speed?

Job No. 9

ENGINE TROUBLES—ENGINE MISSES AT HIGH SPEED

References.—Part Two, pp. 390-2.

Operations Necessary to Perform the Job.

1. Start engine.
2. Test carburetor for correct mixture.
3. Stop engine.
4. Examine spark plugs for condition and point setting.
5. Inspect ignition system for correct timing, loose connections, or defective insulation.
6. Inspect interrupter for condition of points and coil.
7. Examine distributor for moisture, oil, or short circuit.
8. Inspect valves for weak springs, valves sticking in guide, and correct valve clearance.
9. Drain gasoline from carburetor and examine for water.

Description of Operations.

Six main conditions may be located as being the cause of the engine missing at high speed. These conditions are as follows:

1. Spark-plug gaps out of adjustment.
2. Ignition system out of time or defective.
3. Defective insulation.

4. Weak valve springs.
5. Corroded valve stems which cause them to stick.
6. Water in gasoline.
7. Carburetor out of adjustment.

In making tests to locate the trouble, start the engine and test the carburetor for correct adjustment as in Job No. 1. Now stop the engine and remove the spark plugs; examine the points and make adjustments if necessary. If the trouble is not located in the plugs, test the ignition system for timing and loose connections, for oil or moisture in the distributor, or for a short circuit due to some other cause. Weak valve springs should be tested as in Job No. 8, and if found to be defective should be replaced with new, springs. It often happens that exhaust-valve stems become coated with carbon and rust so that the valve, while it closes completely at low speed, does not close fully at high speeds because of its relatively slower action. In this case the valve stems should be polished as shown in Fig. 9*a*.

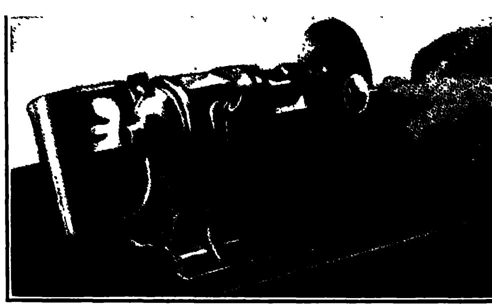


Fig. 9*a*.—Polishing Valve Stems.

Water may have collected in the carburetor or vacuum tank. In this case the carburetor and vacuum-tank drain cock should be opened and a small quantity of gasoline allowed to escape.

If the drain cock underneath the vacuum tank is clogged, insert a long pin or a thin wire through the opening, to remove the sediment. Allow some of the gasoline to run out, close the pet cocks again, flood the carburetor, and again try to start the engine.

Where gasoline drain cocks are provided underneath the carburetor and vacuum tank, they should be opened occasionally and a small quantity of gasoline allowed to escape. Water collects at the lowest point in the carburetor and the vacuum tank, and when the drain cocks are opened, it naturally drains out first.

Questions.

1. How may defective insulation be repaired?
2. How can water get into the distributor?
3. What is a simple test for weak valve springs?
4. If water is found in the gasoline, how may it be removed?
5. What are the indications of an incorrect mixture?
6. Why will a weak spring cause misfiring at high speed?
7. Why may a sticky valve stem cause an engine to miss fire at high speed?
8. How does water get into gasoline?

Job No. 10

ENGINE TROUBLES—ENGINE MISSES AT ALL SPEEDS

Operations Necessary to Perform the Job.

1. Start engine and run at a moderate speed.
2. Test each cylinder by opening priming cock.
3. If misfiring cannot be located this way, short-circuit wires attached to spark plugs and test for spark and defective spark plugs.
4. If spark and plugs are in good condition stop the engine.
5. Determine the firing order of the cylinders.
6. Trace wires leading from distributor to spark plugs for correct wiring to firing order of cylinders.
7. Inspect carburetor adjustments for correct mixture.
8. Test compression for scored cylinder, defective piston rings, leaky cylinder, head gasket, or stuck valves.
9. Take down engine if necessary and make needed repairs.
10. Reassemble all parts.

Names of Tools, Operations and Special Terms to be Reviewed before Performing the Job.

Tools.—Compressometer.

Operations.—" Testing compression," timing engine.

Special.—" Misfiring," " firing order," leaky cylinder, " stuck valves."

Description of Operations.

When an engine " misses " at all speeds, any one of a number of conditions may be the cause of its failure to operate satisfactorily. The success of the repairman in removing the trouble lies much more in his

ability to diagnose the trouble through testing the operation of the engine than through an ability to take down and replace and adjust parts. The main requirements for successful treatment in such cases are an elimination, one by one, of the possible causes of trouble.

When starting, either in warm or cold weather, the engine will not run evenly, unless it is warm from previous running.

During cold weather the engine will have to run a greater length of time in order to warm up to its work properly than in warm weather. Use the choker on the dash. Keep it pulled out part way until the engine temperature rises to a point where the gasoline will vaporize.

The various points mentioned in connection with the engine's not starting should be checked over.

Do not attempt to make any mechanical adjustments or change the carburetor adjustment until the engine has become warm and no doubt exists that it is missing.

The first step would be to determine which cylinder is missing regularly. This may be determined by one of two methods. If pet cocks have been placed on top of the cylinders partially open all of them. A forcible expulsion of gases through the open pet cock with each upward stroke of the piston will indicate that the cylinder is firing correctly. Be certain that the passage through the pet cock is not clogged with carbon. A weak double sound will probably mean that the cylinder is missing because the valves are not seating properly. Another method consists of alternately short-circuiting the plugs in each cylinder to learn which one is missing regularly. That can be determined, since when the plug in the cylinder that is missing regularly is shorted, there will be no apparent difference in the running of the engine. The spark plugs, wiring, and valves of that cylinder can then be checked over.

If the spark-plug porcelain is cracked, current from the distributor, following the point of least resistance, will jump across the gap. This is a "short" within the plug, with the result that the plug will not fire evenly or may not fire at all.

When the cylinder that is misfiring regularly is located, the first step is to examine the spark plug and see that it is in good condition. If the spark-plug insulation is covered with oil and soot, it is evident that it has been misfiring. If the porcelain is cracked a new plug will need to be installed.

One thing to keep in mind is the fact that the engine will not idle evenly with the spark advanced; the spark must be retarded on the steering column before the engine will fire evenly when running idle. With the spark in an advanced position, the running engine will sound as though one or more of the cylinders were missing.

If the trouble is not in the plug determine the firing order of the cylinders and locate the wire leading from the distributor to the cylinder

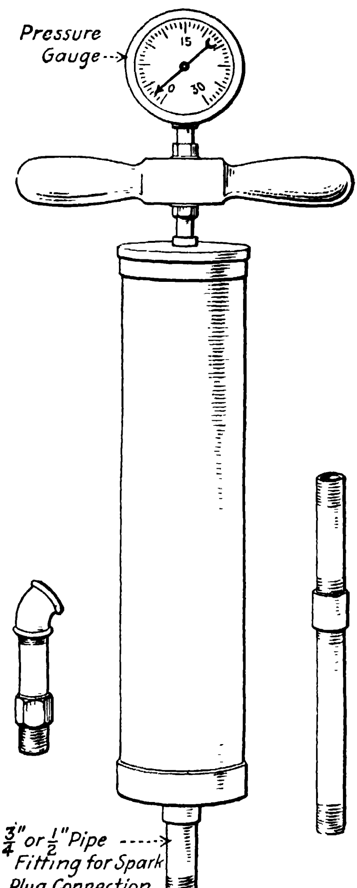


FIG. 10a.—A Compressometer.

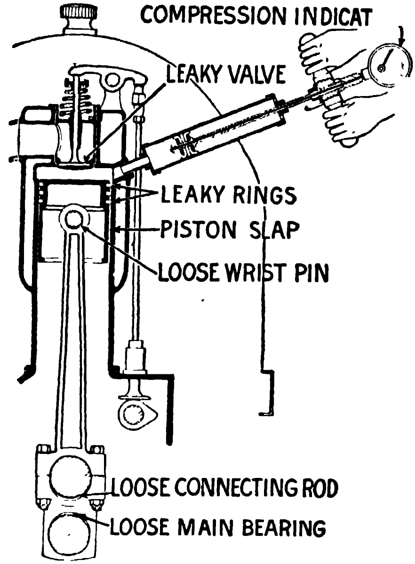


FIG. 10b.—Testing for Compression Troubles, Using the Compressometer.

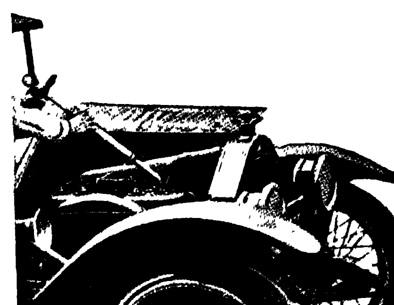


FIG. 10c.—How the Compressometer is Attached to the Engine.

under repair. Examine this wire for breaks or for broken insulation and a resulting " short " located at some point where the wire touches the engine or frame.

If the other cylinders are firing it is evident that the current to the dis-

tributor is in good condition. If the distributor wires have been detached the order for connecting them to the cylinders should also be checked.

In the event that the trouble is not found in the ignition system, the carburetor should be readjusted for a correct mixture.

After making certain that a good spark is obtained and that a satisfactory mixture of gas is delivered to the cylinder, test its compression. This should be done by using the hand-crank to " rock " the piston against the compression, or by a compressometer. If the compression is weak the weakness may be due to a scored cylinder, defective piston rings, leaky cylinder-head gasket, stuck valves, or the valve tappets being set too close.

If the leak is due to cylinder or piston defects, heavy oil poured into the cylinder will often seal the leak long enough to permit the repairman to make sure of its location. When the trouble is located it should be repaired in the manner described in Jobs No. 1, 2, 9 and 10 for the *Engine Work* in Chapter II or in Jobs No. 4, 5, or 6 in *Electrical Work*, Chapter III.

Where a compressometer (Figs. 10*a*, 10*b*, and 10*c*) is available, it can be used to a good advantage to locate leaky valves, leaky rings, a piston slap, loose wrist pins, loose connecting-rod bearings, or loose main bearings. The use of this testing tool requires considerable practice, since the location of the particular trouble depends upon the operator's knowledge of how it responds under each case.

When the instrument is purchased, full directions for its use are furnished by the dealer. Good testers of this kind can be made from a tire pump equipped with the necessary fittings.

Questions.

1. Where are priming cocks located?
2. How is the firing order determined?
3. How is the engine timed?
4. What is meant by " misfiring "?
5. If priming-cock handles are stuck, how may they be released?
6. If the priming cocks are opened, how will you know which cylinder is missing?
7. What should be the position of the gas and spark throttles when testing the operation of an engine for regular firing on all cylinders?
8. What harmful effect does oil have upon the wire insulation?
9. What three conditions are necessary for the operation of any gas engine?
10. Is it likely that an engine would " miss " at all speeds if a wire contact in the primary circuit were loose?
11. If no spark is obtained when the engine is cranked, what may be the trouble?

12. Will turning on the lamps give any indication of the condition of the battery?
13. If the lamps will not light, what may be the trouble with the battery?
14. If the battery is "alive" and the lamps burn properly, will any of the instruments on the dash furnish information as to whether turning the ignition switch supplies current to the ignition system?
15. What appearance should the two mating surfaces of the interrupter contact points present when examined?
16. If the switch is left turned on for a long time, what may happen to the hot-wire resistance unit on the coil?

JOB No. 11

ENGINE TROUBLES—ENGINE RACES

Operations Necessary to Perform the Job.

1. Inspect throttle and spark-control rods for loose or broken connection.
2. Test for "lost motion" or backlash at the control levers on the steering column.
3. Examine intake manifold for air leak.
4. Examine interrupter housing and distributor for condition and correct setting.
5. Examine condition of carburetor controls.
6. If trouble is located, make necessary adjustments or repairs.

Description of Operations.

It is not an unusual thing to find that the control rods leading from the steering column to the carburetor work loose at the connections. When this looseness occurs, closing the throttle lever may not shut off the gas and as a result the engine "races." The same condition may result from a stuck accelerator or a defective spring which should automatically close the throttle when the pressure on the foot throttle is removed.

In a similar way a loose control leading to the interrupter or distributor may change the time of the spark. When the engine races, these controls should be tested, and if a loose joint is found it should be tightened and the engine again tested. Sometimes an excessive "backlash" in the above controls will also produce similar results.

If the cause of racing is not located in the controls, inspect the timer and the carburetor for correct adjustments. A broken spring on the air valve, or a stuck air or throttle valve will cause the engine to race. In this case remove the carburetor and either repair it or replace it with a

new one. After adjusting the carburetor, test its operation. When these conditions are satisfactory, the engine should respond to the controls.

Questions.

1. What kind of joints are generally used on spark and throttle control rods?
2. Name some parts of the engine liable to be damaged from "racing the engine" when running idle.
3. Why would a weak spring on the air valve of the carburetor cause the engine to "race"?
4. How can an air leak in the intake manifold be located?
5. How can you test the gas controls for a loose connection at a joint?
6. What three conditions are necessary if the engine is to be started and is to run properly?
7. What test should be made to insure that there is equal compression in all of the cylinders?
8. How often does the compression stroke occur in a four-cycle four-cylinder engine?
9. How can the driver test for fuel in the cylinders?

Job No. 12

ENGINE TROUBLES—ENGINE WILL NOT ACCELERATE

References.—Part Two, pp. 390-2.

Operations Necessary to Perform the Job.

1. Examine choke valve in air-intake passageway of carburetor for stuck or closed valve.
2. Examine carburetor priming device for disconnected control rod or wire and for a correct setting.
3. Examine auxiliary air-valve spring for stiffness and condition.
4. Start engine.
5. Test carburetor adjustments by changing to a leaner mixture.
6. If engine does not speed up or respond to the throttle, stop engine, test ignition for late or weak spark or incorrect timing, and correct performance of spark governor.
7. If magneto is used, inspect condition of the coupling.
8. Test engine for compression and stiffness.
9. Inspect oil pump and examine oil.
10. Examine valve action for correct setting.

Description of Operations.

This trouble becomes apparent when trying to accelerate on an ascending grade or when the throttle is suddenly opened. One of three main causes will generally be found to be responsible for the sluggish operating condition:

1. A too rich or too lean mixture.
2. A retarded or weak spark.
3. Poor compression.

A rich mixture may be the result of a stuck or closed air valve in the carburetor or of a need for adjustment. The priming wire or rod sometimes becomes disconnected and fails to operate the valve. These conditions can readily be located and are not difficult to repair.

If the carburetor is found to be in a good condition, adjust it for a correct mixture and test the acceleration of the engine. If the engine picks up, it is reasonable to assume that the trouble was due to an improper mixture and that the carburetor should be fully adjusted.

If, on the other hand, no change is observed in the operation of the engine, the condition of the spark should be inspected.

Late or sluggish ignition may be due to several causes and is not uncommon in its occurrence. When this condition exists there is an almost entire lack of power,—the engine heats and causes the water in the radiator to boil. If the ignition is too early, the engine will pound and knock on the slightest pull. To check up the ignition see Job No. 3 for Electrical Work.

It sometimes happens that a primary wire becomes old and the strands broken. Even though one or two of the strands are attached, thus closing the circuit, the additional resistance will reduce the primary current and prevent a hot spark. Badly burned spark-plug points will produce a similar result. These conditions should be remedied by replacing or repairing the wires or spark plugs, and the engine should be tested again.

Poor compression in the cylinders may be due to carbonized valves (see Job No. 1, Chapter II) or to worn or broken piston rings.

When small particles of carbon become lodged on the valve seats they hold the valve away from the seat and destroy compression. The gases leak out before ignition, and the pressure during the power stroke is very much weakened. As a result of this condition there is less power and the operation of the engine is uneven.

To determine which valves need attention, turn the engine by hand and note whether the same degree of resistance is met for each cylinder.

The ones which offer the least resistance have leaky valves or bad piston rings.

It is sometimes difficult to determine the condition of the piston rings, especially when the valves have not been ground. If the car is placed near the breathing tube and the engine cranked by hand, it is possible to hear the " hissing " of the gas as it leaks past the rings.

If the rings are found to be defective, the pistons should be removed and new rings installed as in Job No. 9, Chapter II.

Valves, due to the expansion of the push rods which have been adjusted too close, may also cause weak compression when the engine is hot. Some owners are anxious to have the engine run as quietly as possible and therefore set the valve-tappet adjustment too close. The tappets should always be adjusted with a standard gauge. A little noise is better than a loss of compression.

Questions.

1. Where is the air inlet on the carburetor located?
2. Where is the priming device located?
3. What kind of magneto couplings are generally used?
4. Is it advisable to try to repair the auxiliary air-valve spring, if found too weak or too stiff?
5. For what conditions should the oil pump be inspected?

Job No. 13

ENGINE TROUBLES—LOSS OF POWER

References.—Part Two, pp. 390-2.

Operations Necessary to Perform the Job.

1. Inspect ignition system for correct timing.
2. With ignition switch off, crank engine with starting crank and test compression.
3. Examine battery or magneto for condition, and test spark.
4. Inspect magneto coupling for lag.
5. If no cutout is used on the exhaust pipe, disconnect pipe at muffler, start engine, and test for back pressure and clogged muffler.
6. Drive car at normal speed, release clutch, and let car coast to test for dragging brakes or binding in transmission.
7. If a metallic knock is present when car is accelerated, examine combustion chamber for carbon.

8. With engine running, test carburetor adjustments; correct adjustments if necessary.
9. Try out car on the road and observe whether engine overheats or loses power.
10. Examine cooling system for circulation and water supply.
11. Inspect oiling system for lubrication of engine.

Names of Parts, and Special Terms to be Reviewed before Performing the Job.

Parts.—Cutout, muffler, exhaust pipe.

Special.—" Back pressure," dragging brakes, binding transmission clogged muffler

Description of Operations.

When trouble develops, endeavor correctly to analyze or trace it from result or effect to cause, before attempting to apply a remedy. This analysis is best accomplished by a process of elimination systematically followed step by step until all possible sources have been checked. When the conditions causing the trouble have been located, the remedy is usually self-evident and relatively easy to correct. In most cases the trouble will be found to be due to a condition or conditions which have already been explained in previous jobs. If unable to trace back to the correct source, it is better to call for expert assistance than to experiment or disassemble the engine haphazardly and run the risk of further complicating the trouble.

In general, loss of power is due to one of the following causes:

1. A late or weak spark, or failure of spark governor.
2. Weak compression.
3. Too much back pressure.
4. Dragging brakes.
5. Poor mixture.
6. Engine overheating.

It will be noticed after a little experimenting that driving with the spark lever retarded makes quite a difference in power and speed. For that reason the spark lever should be carried in an advanced position under ordinary driving conditions.

If, from the feel of the engine, it appears that sufficient spark advance is not being obtained, examine the ignition setting and controls and make such adjustments as are necessary. A weak spark will cause slow or sluggish power and as a result the engine will overheat. In some cases the exhaust manifold will become " red hot " from the slow burning of

the gases. Failure of the automatic spark advance or spark governor to function properly will affect the pick-up to a marked degree.

After a car has been used for some time or if it has been run with too much oil or a poor mixture the muffler may become clogged with soot or carbon. This condition will cause a back pressure which will reduce the power of the engine. If there is no cutout on the engine, disconnect the exhaust pipe in front of the muffler and test the engine for power. In case the trouble has been located, the muffler should be removed, taken apart, and cleaned.

When new brake bands have been installed or when they have been recently adjusted, they sometimes drag on the drums, thus causing a loss of power. To test for this condition, speed up the car, release the clutch, and note whether the car will coast freely or whether it soon comes to a stop. When adjusting the brakes jack up the rear end and test the wheels by hand for free action. (See Job No. 19 on Chassis Work.)

If the trouble has not yet been found, test the carburetor and make new adjustments as described in Job No. 1. Rich mixtures not only do not develop power but cause overheating and a resulting loss of power.

The radiator and cooling system should be kept filled with water at all times. If water is lost through leakage, the engine will overheat and lose power, owing to the tendency of the bearing surfaces to "seize" as the metal expands with heat.

If the engine has been driven without water until the engine seizes, be very careful with it. Do not pour water into the radiator until the engine is cool; then drive slowly, and have the engine tested and examined at the first opportunity.

Lack of oil or failure of the oil supply will cause a loss of power, much the same as a lack of water, with the exception that the engine will commence to slow down sooner and will feel stiff or as though it were working very hard. When this effect is apparent, push out the clutch immediately and stop the engine. Running the engine without sufficient oil will very quickly result in injury to the bearings.

Questions.

1. Will overheating cause loss of power?
2. If the muffler is clogged, will the exhaust manifold change color from overheating?
3. Would overheated brake drums indicate dragging brakes?
4. How can the compression be tested with a compressometer?
5. How is the air pressure in tires tested?
6. What are the effects of a weak spark?

7. What are the effects of a rich mixture?
8. What are the effects of a late spark?
9. Which should a good " trouble shooter " use most, brains or tools?
10. If the engine shows a loss of power, name ten conditions any one of which may be the cause.
11. If the trouble is due to weak compression, what conditions may be at fault?
12. If the trouble is in the ignition system, what conditions may be at fault?

Job No. 14

ENGINE TROUBLES—ENGINE OVERHEATS

References.—Part Two, p. 489.

Operations Necessary to Perform the Job.

1. Inspect radiator for water.
2. If a water-circulating pump is used, examine condition of pump and repair or replace same if necessary.
3. Test radiator and cooling sy-tem for clogged cores and obstructions, and examine thermostat.
4. Drain water and examine for foreign matter.
5. Refill radiator with clean, soft water.
6. Start engine and run same at normal speed; remove radiator filler cap and observe if water circulates; if not, stop engine, disconnect hose connections, and inspect condition of hose; replace with new hose if necessary.
7. Inspect fan for loose or worn belt.
8. With the cooling system in good condition, examine the condition of the oil in the crank case. If poor, drain and replace with fresh oil to the correct level.
9. When the cooling and lubricating systems are found to be satisfactory, examine ignition system for a weak or late spark.
10. If a magneto is used, inspect the coupling and test for backlash.
11. When these conditions are satisfactory, start the engine and test the carburetor for correct mixture.
12. If a water-injector device is used, change the adjustment as necessary.
13. Stop engine, inspect the compression chamber for carbon.
14. Examine condition of valves.
15. If the cylinder head is detachable, drain water, remove cylinder head, and examine gasket for leak. If defective, replace with a new gasket, attach cylinder head, refill with water.
16. Inspect valve-tappet clearance for correct adjustment.
17. Examine valve timing for correct setting.
18. Test compression, using a compressometer.

Description of Operations.

Overheating is usually the result of running the engine without sufficient lubrication or without sufficient water.

When overheating occurs through lack of water it makes itself noticeable through a gradual slowing down of the engine, due to the tendency of the bearing surfaces to "seize." If the water supply is insufficient and the engine is very warm, do not pour cold water into the engine at once, but first allow the engine to cool.

Look for the water leaks to determine where they are located, so that they may be repaired. Often the water-pump stuffing-gland nuts need to be tightened or repacked. Water-pump pack nuts are tightened when turned in the direction in which the shaft rotates.

When the water-pump shaft packing needs replacement, remove packing-gland nuts, repack with graphited packing, and replace the nuts.

If the car has been in use for a considerable length of time, or if during the winter season it has been driven with a freezing solution that is liable to eat the interior of the hose connections, make sure that the walls of the lower hose between the radiator and the water pump have not become thin. Where this hose has thin walls the suction of the water pump will cause them to collapse, thus partially shutting off the supply of water to the cylinders. A clogged radiator often causes the hose at this point to collapse. To make this test, speed the engine suddenly and note whether the walls of the hose collapse. Hose having a coiled wire spring inside to prevent collapsing is best suited for duty at this point.

To clean radiator, dissolve several pounds of washing soda in a pail of hot water and pour into radiator. Run engine for thirty minutes and drain system. Flush system with clear water after draining soda solution.

If the fan belt is loose or worn, the fan will not drive at the correct speed and the water in the cooling system will become too hot. If the fan sticks on its bearing through lack of lubrication, the belt will slide over the fan pulley and cause the engine to overheat.

Many manufacturers equip motor cars with thermostats. Some thermostats have winter and summer settings. Consult manufacturer's manual for necessary information.

When the engine shows signs of overheating do not continue to drive it in that condition but proceed at once to locate and remove the cause. The oil-indicator gauge should be observed occasionally to see that oil is passing through the lubricating system.

Overheating resulting from lack of oil makes itself known through pounding noises occurring within the engine and through a gradual reduction of speed. In either case the engine should be stopped immediately and the cause investigated. No attempt to start again should be made until the engine has become thoroughly cool.

A low supply of oil, or very thin oil, will make itself known through a failure of the oil-sight gauge to register. When the oil does not circulate it is due either to a lack of oil within the engine or to a stoppage in the oil line. Examine the oil line and oil-sight gauge, and see that the connections are tight. Air leaks in the line between the oil gauge and in the connections at the oil pump will interfere with the operation of the indicator.

If the oil level is at the proper height, start the engine and observe the oil-sight indicator on the instrument board.

Should the hand not show a pressure, stop the engine at once. Place an additional supply of oil in the engine and proceed at a moderate speed to the nearest point where help may be obtained.

If the engine is operated without sufficient lubrication for any length of time, it may result in serious injury to the bearing surfaces.

If the oil level is at the proper height and the gauge indicates the passage of oil through the oiling system, the difficulty is undoubtedly located in the cooling system, or the ignition-system setting may have been retarded.

Where the connections between the ignition system and spark lever are in good order so that the spark may be advanced, have the ignition setting checked to determine whether the coupling has slipped or whether some other condition of the ignition system is responsible for the overheating.

In a car that has been driven for several seasons it is possible that the gear or chain driving the ignition system and valve timing is worn to the extent that it disturbs the timing. In this event the gear cover should be removed and one of the offset links taken out of the chain or a new gear installed.

Where a water-injector device has been installed on the intake it may be out of adjustment and may thus disturb the condition of the mixture. After an examination of this device, test the carburetor for a correct adjustment as already explained in Job No. 1.

Carbon deposits may form on top of the pistons, cylinder heads, and valves. While the engine will continue to operate smoothly even with heavy carbon deposits, it will lose some of its efficiency and will fire unevenly and develop a loss of power, due to carbon working into the valve seats and not allowing the valves to close properly. An

inferior grade of lubricating oil and a rich mixture will also cause large carbon deposits.

Running kerosene through the engine will aid materially in keeping down carbon deposits. After the engine has been run until hot, the kerosene may be poured into the carburetor air intake. The engine should then be allowed to run idle at a speed of about twenty-five miles an hour. Only a small amount of kerosene should be poured in at a time. Never put in enough to stall the engine. The engine will smoke excessively while the kerosene is passing through and for a few minutes afterwards until the kerosene is burned out. This method will serve to soften the particles of carbon that have collected around the valves, and will also aid in removing the carbon that may have accumulated on top of the pistons.

Where this practice is followed at least once each month, good results should be obtained. One-half pint of kerosene is sufficient at any one time. Feed the kerosene very slowly so that it will not accumulate in the combustion chamber.

Carbon deposits make themselves known through lack of power, causing loss of compression through the valves not closing properly, and sometimes through knocking noises due to pre-ignition.

Pre-ignition is caused by particles of carbon remaining incandescent and igniting the incoming charge in the cylinders before the ignition spark occurs.

The oxygen method of burning carbon has proven satisfactory and can be used to good advantage when the head of the engine is not removable. When the engine has a removable cylinder head, remove the head to clean carbon.

When burning out the carbon, as each cylinder is treated the piston in that cylinder should be brought to a stop at top dead center in order to prevent the flame injuring the cylinder walls. When the oxygen is admitted to the cylinder it is ignited with a match or taper and will burn as long as carbon is present.

After the removal of the carbon it is a good plan to grind the valves as described in Job No. 1 on Engine Work.

In the event that these tests have not located the trouble, remove the cylinder head, if a removable head is used, and examine the head gasket for a leak. Care should always be taken when replacing the head not to injure the gasket and to tighten all of the nuts with the same pressure. Replace the cylinder-head gasket with a new one, each time the head is removed, to secure the best results.

As a final test, inspect the valve-tappet adjustment, and if the engine has recently been overhauled test the valves for correct timing by remov-

ing the gear cover and noting the manufacturer's marks as shown in Fig. 12*a*, Chapter II.

If no marks are found, the valves should be timed in accordance with the manufacturer's instructions and specifications.

Questions.

1. Will overheating cause the engine to knock or pound?
2. Why should soft water be used in the cooling system?
3. Would too much oil in the crank case cause overheating? Why?
4. Can an engine overheat from improper operation? Explain.
5. What are the conditions affecting the cooling system which may cause the engine to overheat?
6. What are the conditions affecting the ignition which may cause the engine to overheat?
7. What are the conditions affecting the lubrication which may cause the engine to overheat?
8. What are the conditions affecting compression which may cause the engine to overheat?
9. Can all of the operations given be classified under the six heads—cooling system, lubrication, ignition, compression, carbonization, and carburetion?
10. What methods are used to remove carbon?

Job No. 15

ENGINE TROUBLES—ENGINE WILL NOT STOP

Operations Necessary to Perform the Job.

1. Inspect ignition switch for short circuit; repair if necessary.
2. If engine continues to run after ignition switch is turned off, stop engine by releasing clutch, engaging transmission gears and re-engaging clutch slowly to stall engine or choke carburetor.
3. If high-tension magneto is used, examine ground wire.
4. Inspect cylinders for excessive carbon.
5. If necessary, remove carbon and grind valves.

Description of Operations.

If the ignition switch has been turned to the " off " position and the engine continues to run, the trouble in most cases will be found in the switch. A " short-circuited " wire may prevent the switch from opening the primary circuit, in which case the engine will continue to run.

The switch should be removed and the inner connections examined for loose strands of wire or for loose parts which may be responsible for the " short."

In case a high-tension magneto is used, the " ground wire " may become detached so as to prevent the switch from completing the " ground " when turned to the " off " position. A full description of this trouble is given in Job No. 8 on Electrical Work.

When an excessive amount of carbon has accumulated in the cylinders, the engine will become heated, owing to the carbon. Some of the particles of carbon will become incandescent and cause the mixture to pre-ignite or to continue igniting after the switch is opened.

The engine will not operate regularly under this condition, but will pound and often stop and run backward because of the pre-ignition. It is not difficult to locate this trouble, and the carbon should at once be removed by scraping. (See Job No. 15 on Engine Work.)

Questions.

1. In what position should the gear-shift lever be kept when the car is standing still?
2. What damage may result from stalling an engine?
3. How is carbon removed?
4. How are valves ground?
5. Why is a ground wire used to stop an engine operating on a high-tension magneto?
6. Could all ignition systems be equipped with a grounded switch in the primary circuit?
7. What damage would result to a battery if a ground were used in the primary circuit?
8. What methods are used to prevent the formation of carbon in the cylinders?

Job No. 16

ENGINE NOISES—ADJUSTING VALVE TAPPETS

References.—Part Two, p. 396.

Operations Necessary to Perform the Job.

1. Examine each tappet adjustment for too much clearance between tappet and valve stem.
2. Examine valve and tappet guides for looseness or wear.

3. Repair or replace as necessary.
4. Examine flywheel for reference marks, adjust the tappets on any one cylinder, determine whether the intake and exhaust valves open and close according to the marks on the flywheel.
5. Measure clearance and adjust balance of tappets to same clearance.
6. If the flywheel is not marked, adjust tappet and allow enough clearance for heat expansion, or refer to manufacturer's specifications for valve clearance.

Description of Operations.

Many car owners object to the tapping noise produced by the valve tappets when they are slightly out of a close adjustment. While too much clearance will retard the opening of the valve and reduce the capacity of the valve opening, it is necessary that the valve be permitted to close freely and without any back pressure on the push rod. If the adjustment is made when the engine is cold, the push rods will expand when heated and trouble may result from too close a setting. Each manufacturer gives the correct clearance for his particular make of car, and care should always be taken to observe these specifications when making adjustments. Jobs No. 1 and 2 in Engine Work illustrate and describe the methods of making these adjustments.

Examine the surface of the valve lifter or the part which makes contact with the valve stem, to be sure the surface is smooth. A recess is usually present at this point after continued use. Excessive play of the valve lifter within its guide will cause a noise.

Questions.

1. What is meant by " reference marks " on the flywheel?
2. What kind of a gauge is generally used to measure the valve clearance?
3. Is there any danger of stripping the threads on the tappet adjusting screws if the lock nuts are drawn too tight?
4. May valves be adjusted if no marks are found on the flywheel? How?
5. What methods are used to reduce valve-tappet noises when designing the engines?
6. What is the average clearance to which the adjustments should be made?
7. When should the adjustment be made, with the engine hot or cold? Why?
8. What repairs must be made to a valve after it has been reseated a num- of times? Why?

Job No. 17

ENGINE TROUBLES—KNOCK IN ENGINE

References.—Part Two, p. 391.

Operations Necessary to Perform the Job.

1. Try to locate knock by turning crank shaft with starting crank to position where knock is the most noticeable, and then rock flywheel if accessible; locate knock and make necessary repairs or adjustments.
2. If knock cannot be located this way, start engine and run at different speeds to test for loose wrist pins, piston slap, loose or worn connecting-rod bearings.
3. Change carburetor adjustments if necessary.
4. Stop engine and test ignition for correct timing.
5. Test for play in front crank-shaft bearing, using starting crank as a lever to pry the shaft.
6. If flywheel is exposed, insert a jack under flywheel, raising and lowering same, and test for bearing play or loose condition.
7. If possible, use a jack handle as a lever to pry between flywheel and crank case to locate end play in crank shaft.
8. Examine cylinders for carbon and inspect condition of valves.
9. Inspect valve-tappet adjustment for incorrect clearance.
10. If trouble is not located, remove crank case for further inspection of bearings.
11. Use compressometer if available to locate loose wrist pins, piston slap or play in bearings.

Description cf Operations.

A knock in the engine is caused by premature ignition, a loose bearing, worn timing gears, or piston slap. To remove the knock, inspect and test out all possible causes of the knock, and after locating the trouble proceed to make the necessary repairs or adjustments. Those who are constantly driving a car soon learn to detect any unusual sound in the operation of the engine and in most cases can locate the trouble without much delay. To one who is not accustomed to operating a car, many of the noises mean nothing, and it often happens that considerable damage is done before the need for repairs or adjustments is realized. Frequently noises similar to engine knocks are produced by defective bearings in the generator or magneto.

When a peculiar pound or knock which is not one of the regular sounds of the engine is heard, it should be investigated to determine

its location and to determine whether further operation without repairs is advisable. Go about the task with optimism and in a careful way. As a rule, no disassembling is necessary to locate the cause. Do not jump at conclusions and begin to take down the engine. It is much better to use brains first and tools afterwards.

Nearly all knocks can be quickly located; then repairs or adjustments should be undertaken.

A bearing knock can be detected in three ways: first, by accelerating the engine quickly, at which time a rattling and clashing sound will be produced; second, by starting the car with the brakes set, which will cause the engine to pull against resistance; and, third, by throttling the engine slowly.

Figure 17*a* demonstrates the most practical method of locating knocks or pounding noises which often occur in a gasoline engine. While the engine is running, hold one end of a screw driver, rod, piece of pipe, or piece of wood, to the car and place the other end at different points on the crank case of the engine. The sound is transmitted along the screw driver or rod, and its location is therefore more easily determined.

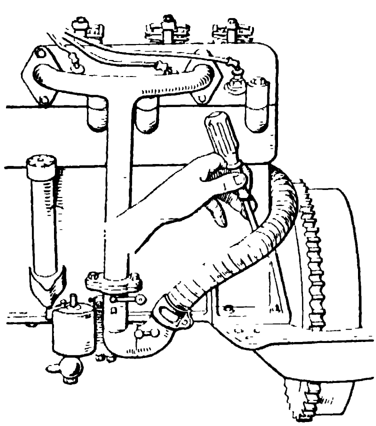


FIG. 17*a*.—Locating Engine Knocks.

If the sound is loudest at the top of the engine, short-circuit the plug on that cylinder. If the noise diminishes, and appears as a double knock, the cylinder in which the trouble lies has been located.

It is difficult to describe the change in sound of engine knocks when the spark plug is short-circuited. Only repeated practice will enable any repairman to diagnose and locate correctly noises of this kind.

The next step is to determine, first, whether the knock is due to a worn or loose piston; and, second, whether it is due to a worn piston pin.

If the engine is cold, run it long enough to heat up thoroughly the pistons and cylinder walls— as a cold engine will always be noisy and is likely to deceive the inexperienced. If the noise is produced by a loose piston, retarding the spark will cause the noise to decrease. Loose pistons cause a slap which is most pronounced when the engine is pulling at low speeds. Detonation is present when the engine is accelerated rapidly. In this case, however, it is best to test the compression of the

cylinders by cranking the engine by hand and noting the amount of compression in each cylinder.

If the noise appears to come from the lower part of the engine, determine whether it is in the main crank-shaft bearings or in the connecting-rod bearings. By holding the screw driver or rod opposite the main bearings and making the engine "pull," the location can usually be determined with reasonable accuracy.

Late or sluggish ignition is not a common occurrence and is best detected by an almost entire lack of power, and also by the fact that the engine overheats.

If the valve timing has changed very much, a dull pounding in all cylinders will result.

If the ignition is sluggish, examine the contact points and spark-plug wires.

Worn or improperly adjusted push rods and valve lifters may also be the cause of the trouble.

These troubles are easily detected, and adjustments or replacements should be made as per instruction on Job No. 16.

Loose nuts on flywheel bolts sometimes cause a noise that is very difficult to locate as the sound is transmitted to all parts of the engine. This noise is most prominent when the engine is idling slowly. The noise is also similar to that caused by loose main bearings.

Noisy valve tappets can be located by slipping a knife blade between the push rod and the valve rocker arm. In this way a tension is placed on the loose tappets, which will cause the noise to disappear. The noisy tappets should then be adjusted.

After making these tests and the adjustments as needed, if the noise still persists, remove the timing-gear case and examine the crank-shaft gear key. If this is in good condition, the trouble is probably due to loose cam-shaft bearings. Replacing the cam-shaft bearings will remedy this condition.

A carbonized engine will pound when the power is applied suddenly or when ascending a slight grade. Retarding the spark will reduce the noise; however, the engine will be sluggish, heat readily, and labor on the slightest pull. This condition is known as a compression knock and is due to the high compression caused by the reduced volume of the carbonized compression chamber, and pre-ignition of the gas charge by the incandescent carbon in the cylinder.

Carbon will deposit in the combustion chamber of any internal-combustion engine. At the first opportunity after a compression knock appears, the cylinder head should be taken off, the carbon removed, and the valves ground or the carbon burned out with an oxygen flame.

Carbon is deposited by the use of inferior gasoline, inferior oil, or an excessive use of both inferior oil and gasoline. It can be avoided to a great extent by using the proper quantity of good cylinder oil and keeping a proper mixture of gasoline and air.

Questions.

1. When using a starting crank to test for play in the front crank-shaft main bearing, which way is the shaft moved to make the test?
2. What should be the appearance of the valves when they are in a good condition?
3. How is a crank case removed?
4. What differences will be noted between the knock due to a loose connecting-rod bearing and that due to a loose main bearing?
5. What causes a gasoline knock?
6. What causes a carbon knock?
7. What causes an ignition knock?
8. Which of the foregoing knocks is the easiest to remove?
9. Do "twin" engines use one or two carburetors? Why?
10. What does black smoke coming from the exhaust indicate? What does white smoke indicate?

Job No. 18

ENGINE NOISES—PISTON SLAP OR LOOSE WRIST PIN

References.—Part Two, p. 403.

Operations Necessary to Perform the Job.

1. Start engine, retard spark, close throttle, and run engine at idling speed, then accelerate engine.
2. If slap is not located, short-circuit spark on each cylinder, testing one cylinder at a time.
3. Stop engine and, using starting crank or flywheel, bring each piston up on compression stroke and rock against compression.
4. Remove cylinder head and inspect cylinder wall for wear.
5. Make necessary repairs.

Description of Operations.

While piston slaps and loose wrist-pin noises often become annoying they are not so injurious as are loose bearings. Whenever they become so apparent as to be easily detected, the necessary repairs should be made.

To locate these troubles start the engine, retard the spark, close the throttle, and run the engine at an idling speed until warm; then speed up the engine by opening and closing the throttle quickly so as to make the piston slap or the loose wrist pin develop a knock. When the knock is located in a particular cylinder or cylinders, the usual repairs as previously described should be made. If the piston slap or the loose wrist pin is not located, short-circuit the spark on each cylinder, testing one cylinder at a time in order to make the slap or wrist-pin knock less noticeable. If the knock is still unlocated, stop the engine, bring each piston up on compression stroke, and while rocking the piston against compression listen for the knock.

A piston slap will be most pronounced when the car is pulling slowly and the throttle is opened to increase the speed.

As a last resort remove the cylinder head, make a final inspection of the pistons, and make the necessary repairs. The compressometer described in Job No. 10 may also be used to locate either of these knocks.

Questions.

1. What causes a piston to "slap"?
2. How are repairs made for a piston "slap"?
3. What may cause a wrist pin to become loose?
4. Is it advisable to make repairs for worn wrist pins or is it better to replace them with new parts?
5. How is a cylinder head replaced?

Job No. 19

ENGINE NOISES—REMOVING PRE-IGNITION KNOCK

Operations Necessary to Perform the Job.

1. Test for spark knock by removing valve caps and inspecting cylinders for carbon.
2. Replace valve caps and inspect ignition for early setting.
3. Start engine and test carburetor for lean mixture.
4. Inspect spark governor.

Description of Operations.

The noise known as a spark knock is sometimes spoken of as a pre-ignition knock and may be due to too much carbon in the cylinder,

to an advanced spark, or to a very lean mixture. The sounds coming from the engine will not always enable the operator to locate or to distinguish the sources of trouble. As a rule, however, it is not a difficult job to analyze the sounds and to locate the cause. If the trouble is due to carbon, it will not show up until the engine gets hot, and it can then be definitely located by removing the spark plugs and inspecting the cylinders for carbon deposits. If an excessive amount of carbon is found, it should be removed as in Job No. 15 in the chapter on Engine Work.

It sometimes happens that the spark throttle is too far advanced or that the spark-control adjustments have become loose and the spark occurs too early. To locate the trouble, retard the throttle and listen to the engine noise. If the noise is not removed, examine the controls and ignition setting and repeat the test after making such adjustments as seem necessary. (See Job No. 3 in Electrical Work.)

Certain grades of engine fuels cause the engine to " ping " when it is accelerated rapidly. A very lean mixture will cause the engine to knock when accelerated. Two cylinder-head gaskets will aid in eliminating the " ping " when the engine is of the removable-head type. The knock can be eliminated by overhauling and adjusting the carburetor as in Job No. 1.

Questions.

1. How may stuck valve-chamber caps or plugs be removed?
2. What is the average distance a good spark will jump from a disconnected high-tension wire to a plug?
3. What is meant by " pre-ignition " ?
4. How may carbon cause a knock?
5. What causes a fuel knock?
6. What is the average ratio of air to gas in a good fuel mixture?

Job No. 20

PISTONS STUCK

References.—Part Two, p. 397.

Operations Necessary to Perform the Job.

1. Inspect for lack of oil, poor oil circulation, and poor grade of oil.
2. Inspect bearings, pistons, and piston rings.
3. Examine water circulation.
4. Look for water in the cylinders.
5. Inspect for a bent connecting rod.

Description of Operations.

When the pistons are "stuck," "seized," or "frozen," do not attempt to use the self-starter. If the starting switch is closed and the motor armature cannot turn, due to a stuck piston, an excessive current will flow from the battery through the motor windings. This current will quickly discharge the battery and may ruin the starting motor. After examining the engine to make sure that all parts are free to move, test the engine by cranking with the hand crank, or by rocking the flywheel. If the pistons are found to be stuck, inspect the oiling system for lack of oil, poor oil circulation, or a poor grade of oil.

The "seized" condition may also be due to poor water circulation or to water in the cylinders. To release the pistons, prime the cylinders with coal oil and crank the engine a few turns by hand.

After the pistons are released, prime the cylinders with a good grade of cylinder oil and crank the engine again. If the pistons move freely, start the engine and try it out. If the trouble is not yet overcome, remove the crank case for an inspection of the bearings and make all necessary adjustments.

If the trouble has not yet been located, it may be due to a bent connecting rod. In this case the rod must be removed and straightened. A jig should be used to test the connecting rod for line-up between the wrist pin and main-shaft bearings. Frequently the starter pinion and flywheel gear bind and cause the engine to stick. Examine the starter gear first, before dismantling the engine.

Questions.

1. What is meant by "rocking a flywheel" ?
2. What causes pistons to stick?
3. How may water get into the cylinders?
4. Is it better to remove spark plugs when priming with cylinder oil? Why?
5. When changing oil in the crank case, how should the case be cleaned?

CHAPTER V

BODY AND RADIATOR WORK

Job No. 1

WASHING AND POLISHING THE CAR

Operations Necessary to Perform the Job.

1. Remove all dirt with slow stream of cold water.
2. Wash car with sponge.
3. Use kerosene to remove grease from chassis.
4. Wash with body soap.
5. Rinse with clear water.
6. Dry with chamois.
7. Finish with body polish, if wanted by owner.
8. Wash windshield with soap and water; if necessary, clean with Bon Ami.

Names of Materials to be Reviewed before Performing the Job.

Materials.—Body polish, body soap, Bon Ami, kerosene, sponge, chamois, flannel cloth.

Description of Operations.

Lack of washing and lack of care in washing will do more toward ruining the appearance of a car than any other thing. The car should be regularly and systematically cleaned and renovated. The varnish on a new car is always benefited by frequent washing with clear pure water. This hardens the varnish and does much to preserve its brilliancy and luster.

If mud is allowed to dry and harden on the body, when the body is washed the finish will have a spotted and streaked appearance. The mud takes up the oil from the varnish and destroys the luster. Mud and dirt from public roads traversing lime districts are likewise destructive to both luster and fabric of the varnish, the latter disintegrating under the effects of lime.

If the car is not frequently and regularly washed, the finish will often

become dull and spotted, owing to the effects of various gases. The atmosphere of many manufacturing cities is so poisoned with deleterious fumes that the finish of the too infrequently washed car loses its luster in a comparatively short time.

As the best varnishes require time to season, it is advisable to exercise special care in the treatment of the finish during the first one or two months the car is in service. During warm weather, frequent baths of pure, cool water will do much to prevent permanent marking of the finish. To take proper care of the body finish, the following supplies should be available:

Two clean, soft "wool" sponges.
Two 10-quart pails.
Several clean, soft wiping chamois.
A quantity of canton flannel.
A quantity of Ivory or pure castile soap.
Clear running water.
A soft woolen duster.

The two sets of pails and sponges are recommended, so that the pail and sponge used for the first washing may be kept separate from those used in the final washing.

New sponges usually contain sand and shells. These, as well as new chamois cloths, should be cleaned thoroughly with soap and hot water before using.

The object in washing is to remove the dust and mud and to leave the surface clean and dry, with just as little scratching and rubbing on the finish as possible. To wash the car, first, play a gentle stream of clear cool water on all parts until the mud is thoroughly softened and mostly removed. To avoid scratching the finish, the nozzle coupling should be removed from the hose end. Second, remove all oil or grease spots with a cloth or piece of waste saturated in kerosene. Third, remove all mud by rubbing gently with a clean sponge, using an abundance of clear cold water. Rinse the sponge frequently in clear water. Fourth, rub the surface dry with gentle strokes of the rubbing chamois, wringing it out as the water is absorbed.

Rubbing with sponges and chamois should be done in straight lines rather than in circles. To prevent water drying and spotting, it is well to clean one panel at a time. Avoid applying chamois, and especially the sponge, with any great pressure, and do not rub after the surface is dry.

Dust should be removed with a stream of water, rather than with a duster or a cloth. To remove light dust, however, an ordinary woolen

duster is effective. A feather duster should never be used, as it will scratch the finish. Do not attempt to clean the surface with a chamois after using the hose, without first washing the surface with a wet sponge. The surface may look clean after washing with the hose, while at the same time fine particles of grit are retained. It is best to keep the sponge and chamois away from all grease or oil, since when oil-soaked they retain grit. To clean the sponge, wash it in gasoline. Avoid patent preparations, as most of them are ultimately injurious to the finish and their oils will collect grit and cause scratching.

To prevent checking the varnish, avoid subjecting the car to extreme heat, such as standing in a very hot sun. Whenever possible, it is best to avoid sudden changes in temperature.

The bulk of the mud, dirt, oil, and grease will, of course, be found on the chassis and under parts of the fenders. After loosening all the mud possible with clear water, the oil and grease may be removed with kerosene followed by a soap solution.

A good soap solution is made by dissolving a pound or two of soap in a gallon of warm water. This solution will last for a number of washings. Extreme care should be used to secure a soap which is free of alkali, such as pure castile or Ivory. This solution rubbed on with a clean sponge will also remove the oil and grease. The soap water should be thoroughly rinsed off of the surface. Never use the same sponge for this preliminary work that is employed for washing the body.

It frequently happens that the luster on an engine hood is completely lost. This condition is due to washing the hood before the engine has cooled.

To prevent nickel from tarnishing, rub the surface frequently with an oily cloth. This treatment will preserve the brightness without frequent polishing.

Brushing and the use of castile soap and water are all that is needed in the case of leather upholstery. Avoid the use of gasoline, as this is injurious to the leather, causing cracks and a deadening of the luster.

The application once a year of a mixture of three parts of linseed oil and one of vinegar to leather upholstery acts as an excellent preservative and prevents cracking. Apply the dressing with a cloth, and rub it well in between the folds. Allow the dressing to stand about an hour, after which wipe the surface carefully with a clean cloth to prevent soiling the clothing of the passengers.

After a car has been exposed to the air and to the weather conditions for some time, the finish of the body naturally loses its luster and becomes dull. At this time the judicious use of a little body polish will aid mate-

rially in restoring the finish to its natural color. However, this treatment is only temporary and repainting will soon be necessary.

If the finish is very dull after washing, saturate a small pad of selected soft waste with water, dip it lightly into fine rotten stone, and gently rub the dull surface. Do not make a mistake and use pumice stone, for pumice will completely destroy the finish. Rub the surface with the pad and rotten stone until it shows a bright luster.

Rotten stone has relatively no abrasive effect on gum varnish, but does rapidly abrade the imbedded deposit if the varnish is free from oil and grease. As fast as this deposit is cut away the varnish acts as a lubricant, as the easy sliding of the rotten-stone pad will indicate. After polishing, remove all rotten stone with a dampened cheesecloth.

If the finish is only slightly dulled, rub it with a mixture of 1 oz. of rotten stone and 3 oz. of linseed oil instead of rotten stone and water. Shake the mixture frequently whenever it is used.

To Use the Polish.—Use a standard make of automobile polish, and apply as per manufacturer's directions. The luster can be determined by wiping the parts occasionally with a clean cloth or with the palm of the hand and looking at the surface as into a mirror. A perfect reflection should be obtained. If a dullness appears after the car is used, it will indicate that the deposit was not entirely removed with the rotten stone or that the polishing was not thoroughly done. Hard, persistent rubbing will always bring the desired results.

After polishing, wipe off all surplus polish with a cheesecloth, dampen a piece of cheesecloth with alcohol, shake the cloth until it feels cool, but is not damp, and wipe the entire polished surface to remove all traces of oil and to leave the varnish clean and brilliant.

Questions.

1. Why should the nozzle be removed from the hose when giving the body its preliminary wash?
2. About how many coats of paint are used on the average car?
3. Why should a dry surface never be rubbed with a dry cloth or brushed with a feather duster?
4. What effect does it have upon the surface to rub it with rotten stone and oil or water?
5. What effect will drops of alcohol have upon the varnished surface?
6. Is it important to partly dry a cloth which has been moistened with alcohol before using it to clean the polished surface? Why?
7. What effect will water have upon the ignition system?

Job No. 2

REPAIRING TOP AND UPHOLSTERY

Operations Necessary to Perform the Job.

1. Tighten loose screws.
2. Replace tacks in upholstering and top.
3. Tighten or replace rivets and nuts on top frame.
4. Clean and dress top and upholstering.

Description of Operations.

The owner or operator will find it worth while to keep the top and upholstering in good repair. One missing tack makes it much easier for the next one to loosen, and soon the leather or cloth begins to tear and it becomes impossible to restore either to its original condition. A loose screw or bolt causes unnecessary noises and wear in the moving parts. It is good economy to inspect the entire top every week to locate all defects and to make immediate repairs.

So called "one man" tops are supported on windshield standards and produce a greater amount of vibration than the older types. If all nuts and screws are kept tight no damage will result, but once a screw starts to loosen the strain on the other points of support is greatly increased.

Once each year the top should be gone over with a good, standard top dressing in order to preserve its waterproofing and to restore its appearance.

Dust on the outside of standard tops should be removed with a sponge and soap suds. Use plenty of clean water to remove all traces of soap. The inner or cloth side should be dusted with a whisk broom or a stiff brush. Remove all stains with soap and water, but use a brush instead of a sponge. The cloth side should be washed and dried more carefully than the outside. Impure water or soap may change the color and make it necessary to go over the entire lining, in order to obtain a uniform color.

Carriage dressings and gasoline are generally injurious to either the inside or outside, as they will kill the luster and cause the material to harden. Before lowering the top, release the forward fasteners of the rear gypsy curtains, folding them toward the rear, to prevent them from being torn by the bow carriers.

Seat covers may be cleaned in the same way as the lining of standard tops. When the top is folded always use the top cover, otherwise the

extra tire, due to the rubbing action, will soon wear through the rear window. Side curtains should be wiped with a moist cloth before being stowed away. Removing dust and grit from the side curtains will help to keep the celluloid window lights from becoming scratched.

Celluloid windows that have been scratched may partially be restored to their original transparency by applying a coat of acetone varnish.

The ordinary vacuum cleaner, if available, will be found most effective in removing dust from the inside of the car, in addition to cleaning the upholstery and carpets. The air pressure from the tire pump may also be used to blow dust and dirt out of cracks and corners.

Before preparing to fold down a " one man " top see that the curtains are folded neatly and placed in the bag provided for them.

Open the bow-socket holders so that they will receive the top when folded back. Release the catches holding the top to the windshield, raise the top until nearly vertical, pull down on the front bow sockets, causing them to give where hinged and thus allow the top to fold in place. See that the top material is compactly folded between the bows before clamping down the bow holders, and then apply the top slip cover, putting it on carefully without jerking.

When raising the top, first remove the top slip cover, unfasten the bow holders, and, standing in the center of the car, grasp the front bow in the center and pull the top up toward the front of the car. As the top comes up pull down on the front bow, at the same time pressing up on the center bow. When straightened out it can be drawn into position and attached to the windshield.

Do not jerk the top in order to close or open it when putting it up or down. Jerking will not help and may result in injury to the bows or bow sockets. Do not fold up the curtains or put down the top while it is wet.

When folding the curtains, do not fold the celluloid windows, especially in cold weather, as this is likely to crack the celluloid. The construction of the curtains usually permits them to be folded and stored away without the necessity of folding the celluloid sections.

Questions.

1. Is it better to keep the top up than to ride with it folded in its envelope?
2. What are " Gypsy" curtains?
3. What should be used to clean the leather of the upholstering?
4. What may be done to the top to prevent moisture seeping through?
5. What materials are used in tops? In side curtains?

6. What materials are used in upholstering?
7. What may happen to the seat cushions if the storage battery located under the seat gets too hot and begins to give off gas bubbles?
8. What may happen if a hydrometer wet with acid from the storage battery is laid on the seat cushions?

Job No. 3

REPAIRING DOOR RATTLES AND REMOVING BODY SQUEAKS

Operations Necessary to Perform the Job.

1. Clean and repair hinges and catches.
2. Lubricate hinges and catches.
3. Replace rubber bumpers.

Description of Operations.

Strips of anti-squeak material are used to separate the body from contact with the sills. If the doors do not fit properly, place thin shims either under the body support brackets or under the rear sill so as to secure a realignment.

Door hinges and door locks attract a great deal of dust and dirt. On account of their being exposed, it is undesirable to oil them excessively for fear the oil will soil the clothes of the occupants of the car. Nevertheless, a small amount of lubrication is necessary to eliminate squeaks and prevent rusting. For this purpose, ordinary engine oil is unsuitable as it runs away and absorbs dirt very quickly. A better preparation is linseed oil with which a little fine, powdered graphite is mixed. Linseed oil has less tendency to run and spread over a surface than have the common mineral oils. Furthermore, it tends to become gummy and is therefore more effective in retaining the graphite at the required spot for a greater period of time.

When the body has been allowed to become loose at the joints the framework begins to squeak. Linseed oil and graphite may be used to eliminate the squeaking. This preparation should be squirted into the joints at the base of the door posts or at the front end of the cowl. It is sometimes necessary to remove the trimming to eliminate these squeaks, but the effects are of such lasting quality that it is well worth the effort.

The bumpers on the doors require renewal in proportion to the amount of usage they receive. New door bumpers are on hand in every service station so that they may be replaced whenever necessary.

Neglecting to replace door bumpers results in worn hinges and locks. To repair door bumpers, remove the keeper holding the bumper in place, adjust the rubber to eliminate any free play when the door is closed, and screw the keeper in place. Shims may be used under the bumpers to bring them out to position, as an emergency repair.

A great deal of annoyance may be caused by a squeak in the body or chassis. A squeak in the chassis indicates lack of lubrication in some of the working parts and should be attended to at once. If the squeak is present when the car is standing with the engine running idle and the clutch out, it will be found in the engine or clutch hub. If the squeak is produced by letting in the clutch with the gears in neutral it will be in the clutch operating collar or the universal joint.

Perhaps the most annoying squeak is caused by the motion of the body on the frame. This is due usually to loose body bolts. These should be gone over occasionally and tightened. If a fender or running-board skirt should become bent in such a way that the edge of the metal touches against some other metal part, a rasping noise will be caused when the car is in motion, particularly in going over a bump.

Questions.

1. How may a body squeak be located?
2. What are the indications of fender squeaks?
3. How may a fender squeak be removed?

Job No. 4

REPAIRING WINDSHIELD

Operations Necessary to Perform the Job.

1. Remove old windshield.
2. Place new glass in frame if old is broken.
3. Replace windshield.
4. Lubricate and adjust hinges.

Description of Operations.

The repair of a broken windshield glass should only be undertaken by a general repairman when a ready-cut glass can be obtained. Where the glass must be cut it is better to take the windshield to a plate-glass shop for cutting and fitting. Most windshields are made adjustable for rain, vision, and ventilation by swinging the glass in or out. Friction stops hold the glass in any position and may be tightened by turning

the adjustable nuts on the posts. The large nuts which fasten the windshield posts to the cowl bracket should be kept tight at all times. Be sure that the windshield hinges are kept tight. This not only prevents rattling, but insures against breakage of the glass through a sudden collapse of the windshield.

It is a good plan occasionally to put a drop or two of oil on the working parts of the windshield. Lubrication of these parts will keep them in a free working condition and will assist in eliminating squeaks. If the latches or clamps wear so that the top works loose, file a slightly deeper slot in the knob on top of the windshield support. When the latches or clamps become badly worn they can be replaced.

Questions.

1. What should be used to clean the glass of the windshield?
2. What kind of glass is used in the windshield?
3. What devices are used to keep rain or moisture off of the windshield so that the driver's view will not be obstructed?
4. Will Bon Ami scratch the windshield glass if used for cleaning?

Job No. 5

REMOVING OLD AND INSTALLING NEW BODIES

Operations Necessary to Perform the Job.

1. Check all tools and supplies in car body and store in stock room.
2. Remove fenders.
3. Remove body fasteners.
4. Lift body from frame with hoist or by hand.
5. Install new body and fasten same to car.
6. Inspect body cushion liners, check alignment, and test for possible noises.
7. Clean body.

Description of Operations.

The preparation for the removal of the body is not difficult. Care should be taken to protect the finish of the body from injury due to tools or hoisting equipment. If a hoist is to be used, it is better to raise the body and insert cross timbers for attaching the ropes or chains. Precautions must also be taken to balance the body so that it will be secure and not become dangerous to the workmen.

The replacement of old bodies or the installation of new bodies requires considerable care to prevent squeaks or noises.

The sill, or framework, of an automobile body is necessarily made of wood. In order to secure it rigidly to the frame, a number of bolts are required, but as these bolts are set in wood they have a tendency to loosen after the first few hundred miles of service. Body bolts should be tightened every month for the first three months. After that time, if there is no continual tendency to loosen up, they will remain tight indefinitely.

Perhaps the most frequent causes of dissatisfaction with modern automobiles are the squeaks and rattles which seem to emanate from the body. Few owners realize that these are aggravated by neglecting to see that the body bolts are always kept tight.

Some bodies are fitted with graphited shims or liners placed between the sill and the sill frame to eliminate all contact between wood and metal. These shims are square in form and have a hole in the center through which the body bolt is passed. This holds the shim in place and insures its being drawn down tight. The graphite with which these shims are impregnated will last for many months, but in extremely damp climates or in a car which receives more than the average amount of mileage on country roads, it is possible that the shims will need regraphiting more frequently. To do this, it is only necessary to loosen the bolt, wedge a chisel or pinch bar between the body and the frame, and pry the body upward so as to allow a separation of the shims. A knife may then be used to spread the graphite between the shims.

If the above items are neglected and the body is allowed to remain loose on the frame, a great deal of objectionable noise will result. In addition to the noise, serious damage may be done to the framework of the body. It should be clearly understood, therefore, that the rigidity and long life of a body depend entirely upon its being securely bolted to the frame. As soon as it is allowed to become loose it is weakened, squeaks and rattles cannot be eliminated, and the joints in the metal panels sooner or later open up.

After the new body has been installed it should be washed and polished as described in Job No. 1.

Questions.

1. What are the most common types of bodies?
2. What is a "shim" or "liner"?
3. How are bodies constructed?
4. What precautions are necessary in polishing a body?

JOB No. 6

REPAIRING FENDERS, HOOD, APRONS, OR RADIATOR SHELLS

Operations Necessary to Perform the Job.

1. Remove fender or part as necessary.
2. Straighten part, using wood, rawhide, or rubber mallet to prevent marring metal and finish of car.
3. Replace part, clean, and polish.
4. If part cannot be repaired by ordinary tools and methods, replace with new parts or send job to a body-repair shop.

Names of Parts to be Reviewed before Performing the Job.

Parts.—Hood, hoodsill, hood handle, hood fastener, hood-fastener bracket, engine shield, engine-shield fastener, engine-shield bracket, running board, linoleum covering, outside binding, inside binding, front binding, rear binding, shield, fender, fender-support socket.

Description of Operations.

Where fenders have been bent or broken, temporary repairs may often be made without removing them from the car. Where this is possible, there is no danger that the parts will not fit when reassembled. If the damage is due to a collision which has caused dents in the metal,

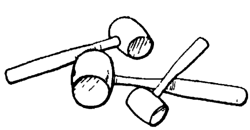
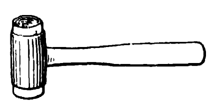




FIG. 6*a*.—Rubber Mallet. FIG. 6*b*.—Rawhide Hammer. FIG. 6*c*.—Rawhide Mallet.

great care must be taken to prevent a permanent marring of the appearance of the metal part.

In Job No. 7 a more detailed description is given of the removal of dents. When the fender is broken or weakened, a support may be riveted or welded (by an oxy-acetylene welder) to the under side of the part.

Wooden timbers with screw jacks should be used to force bent members back into an alignment. As the part is gradually forced back, use a hammer (Figs. 6*a*, 6*c*) to aid in restoring a permanent set. When ham-

mering on fenders always back up the part with a wooden block (Fig. 6*d*) or other device, to give support and prevent vibration. Fender squeaks are usually the result of loose nuts and bolts. To remove the squeak see that the nuts are tightened and see that the bolts holding the hood rail in position and the apron of the front fender are kept tight.

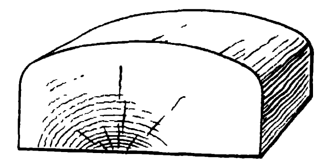


FIG. 6*d*.—Curved Block of Wood for Backing Up.

Where ordinary methods will not restore the part or on jobs where original finishes are to be obtained, the work should be sent to a body-repair shop.

Questions.

1. What will determine whether the old fender, hood, or radiator cover should be repaired or a new one installed?
2. What tools should be used in repairing body parts?
3. What damage may result from vibration of the metal caused by hammering?
4. How may the vibration be prevented?

JOB NO. 7

REPAIRING DENTS IN BODY

Operations Necessary to Perform the Job.

1. Where the dent is easily accessible, straighten the metal, using proper tools and backing up support on opposite side.
2. Replace all parts removed, and clean car.

Description of Operations.

The removal of dents from the body, as a rule, requires an experience and skill beyond that expected of the general repairman. Where high-class work is desired on new or expensive cars, it is best to send the job to a body specialist.

A careful and patient workman can restore ordinary dents so that the part is in its original condition. Before attacking the job of removing the dent, see that free access to both sides of the metal is open to the tools to be used. Where necessary, remove or loosen the upholstery and fit the right tool or backing-up block (see Figs. 7*a* and 7*b*) to the shape to which the dent is to be restored. Place the wooden or metal

backing-up support in position and begin to draw the metal back into its original position. This may be done by the use of a hammer (Fig. 7*a* and Fig. 6*a*) applied at the proper point. Too much hammering will cause the metal to expand and will produce a permanent change in its shape. Oftentimes, by using a rubber, wooden, or rawhide hammer, the original finish of the surface can be restored.

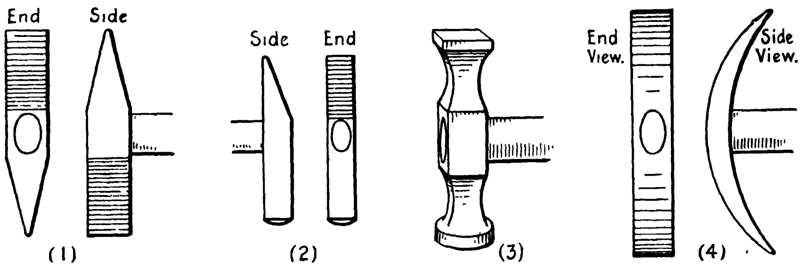


FIG. 7*a*.—Special Hammers for Fender and Body Repair Work.

Where the dent is large it is often possible to place a screw jack in position and to exert a steady pressure which will materially assist in forcing the member or part back into position. Where fenders are removed, it may be necessary to refit them to the car after they have been straightened.

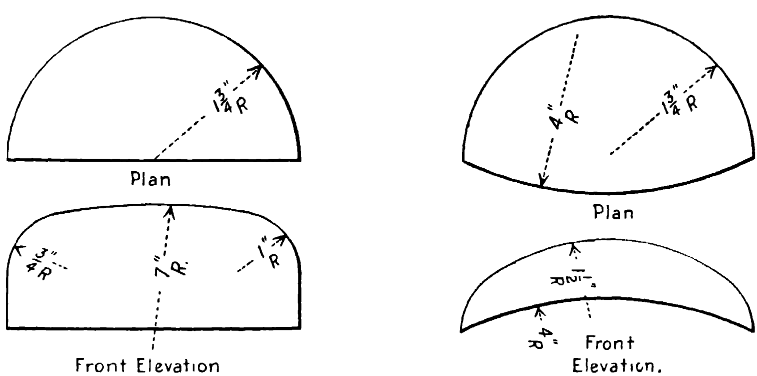


FIG. 7*b*.—Iron Blocks of Different Shapes Used to Remove Body and Fender Dents.

As a rule the metal worker, when forming a sheet of metal, places a support back of all parts except that which is to be shaped, and then by light blows forces this part into the desired position. The expert workman soon collects a special set of tools, each of which is used for some special purpose. Among these are the blacksmith's puller, a

cross-peen hammer, mallets, half-round files, a screw jack, shaped wooden blocks, rounded metal backing-up hand anvils (usually made of babbitt metal), and an assorted lot of iron backing-up blocks of different shapes and sizes. These are shaped to fit the curved surfaces of the body and fenders. Fig. 7*b* shows several iron blocks to be used for this purpose.

After the dent has been partly removed, pass the hand over the part to locate uneven points. Then, by repeated light blows, first with a wooden or copper hammer and then with a steel hammer, remove the small indentations.

A file and emery cloth can then be used to smooth the surface before repainting. The surface should be thoroughly cleaned with turpentine before applying a coat of paint, in order to insure the paint sticking to the surface.

If a careful job is required, it will take several days to apply the necessary coats of paint and to rub down the surface to a good finish. For ordinary jobs a quick-drying Japan paint can be used.

Questions.

1. How should the hammer be applied to draw the metal into the desired shape?
2. What are the tools used in body work?
3. How are fenders and bodies made?

Job No. 8

CLEANING RADIATORS

References.—Part Two, p. 489.

Operations Necessary to Perform the Job.

1. Drain radiator.
2. Fill with soda solution.
3. Wash out all the solution.
4. Fill with clear water.

Description of Operations.

The repeated explosions in the cylinders create considerable heat, and in order to make lubrication possible and keep the engine temperature within workable limits, the excessive heat must be removed. This

is accomplished by the cooling system (Figs. 8*a* and 8*b*) wherein water is caused to circulate around the cylinders. The water enters the jackets at the bottom, and in flowing upward absorbs the surplus heat and passes out at the top into the radiator mounted on the front of the car. The hot water entering the top of the radiator circulates downward through many thin-walled tubes which offer a large area of cooling surface to a constant stream of air passing through the radiator when the engine is running. The flow of air is caused by the movement of the car as well as by the rapidly revolving suction fan located just back of the radiator.

By the time the water reaches the bottom of the radiator it has lost most of its surplus heat to the air. It can now be used again, and is drawn out through the lower hose connection, forced up into the cylinder jackets by the water pump, and continues to circulate in the cooling system while the engine is running. This loss of heat is a direct loss of power and represents about 35.8 per cent of the fuel value of the gasoline. (See Fig. 158, Part Two.)

The water (Fig. 8*a*) is circulated by means of a centrifugal pump mounted on the engine and driven by gears from the crank shaft. The pump is lubricated by grease cups, the handle of which should be turned to the right two or three turns once every 300 miles. Should water leak out around the pump shaft, tighten the packing nuts by turning them in the direction in which the shaft rotates. If this does not overcome the leak, the nuts should be unscrewed and the packing glands repacked.

The radiator must be kept filled with clean water. If the water is allowed to become low, the engine will overheat and steam will issue from the radiator vent tube. If the water in the radiator steams when the radiator is full, the trouble may be due to a stoppage in one of the hose connections. In the course of time the rubber lining in the water hose is apt to separate and, by breaking loose or bulging, to restrict the flow of the water.

Under normal conditions the water in the radiator becomes very hot, but should never boil. Should it persist in boiling when the circulation is not impeded, the trouble may be due to the formation of a scale or coating on the interior of the radiator. This scale can be removed in most cases by uncoupling the hose connections, and, after plugging up the holes, filling the radiator with a strong saturated solution of common washing soda and water. Allow the cleansing solution to stand in the radiator for several hours, then drain it off and flush out the interior by directing a strong stream of water through the filler tube.

Once a week it is a good plan to open the radiator drain cock and let all the water and accumulated dirt run out. If the water is very dirty,

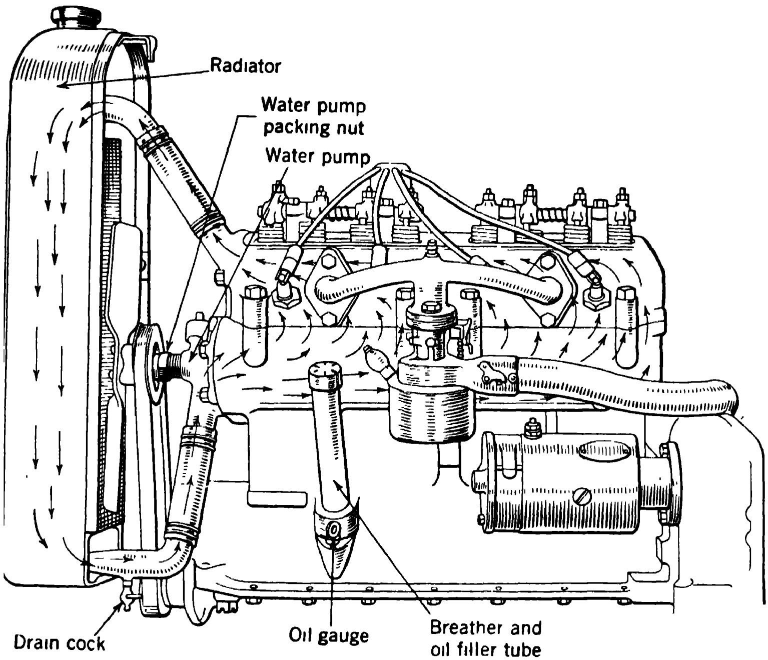


FIG. 8a.—Cooling System. (Chevrolet.)

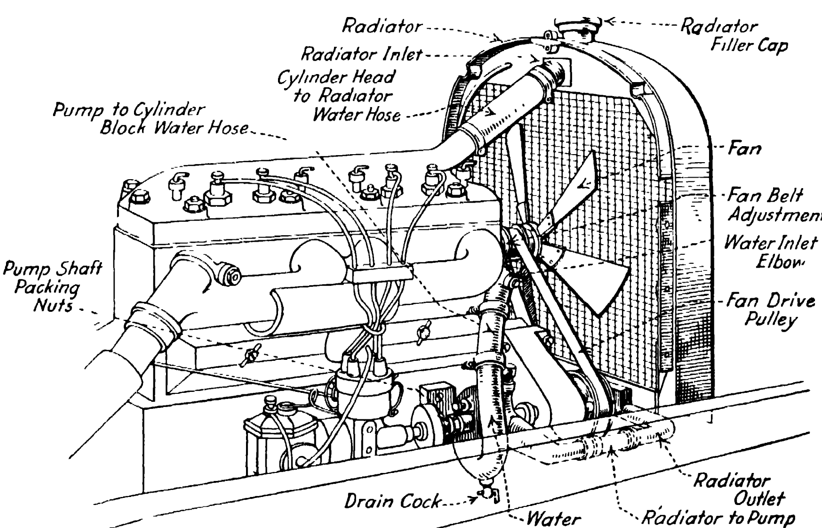


FIG. 8b.—Cooling System.

flush the radiator with fresh water. *Never* put cold water into the radiator while the engine is hot. By " hot " is meant any temperature which is uncomfortable to the hand when held against the cylinder head.

When an engine gets hot the cylinder walls, and especially the cylinder head around the exhaust ports, are thoroughly heated up. Test the temperature of the engine by raising the hood and placing your hand on the cylinder head. If you can hold it there in comfort, water can be placed in the radiator; if not, wait until you can.

Questions.

1. What causes the engine to overheat?
2. What causes scales to form in the circulating system?
3. What are some of the different types of radiators?
4. What methods are used to cause the water to circulate?
5. Why is the radiator made with small tubes or cells having thin walls?
6. What is a motometer?
7. At what temperature does water boil?
8. At what temperature does water freeze?
9. At what temperature of the water in the cooling system will the engine give the best results?
10. How are radiators cleaned?

JOB NO. 9

REPAIRING LEAKS IN RADIATOR

References.—Part Two, p. 489.

Operations Necessary to Perform the Job.

1. Drain water.
2. Remove radiator.
3. Test for location of leak.
4. Solder leak, using soldering iron or Prestolite torch and wire solder.
5. Test radiator for additional leaks and repeat until job is finished.
6. Reassemble all parts.

Names of Parts, Tools, and Materials to be Reviewed before Performing the Job.

Parts.—Radiator core, radiator shell, upper tank, radiator lower tank, radiator filler-cap, radiator strainer, radiator drain cock.

Tools.—Soldering copper, torch, fire pot, testing plugs, tank pressure gauge, iron-topped work bench, acid pot, wire brushes, snips, pliers.

Materials.—Wire solder, soldering paste, muriatic acid.

Description of Operations.

Radiator leaks are common to all types of water-cooled cars. The leaks may be due to frozen water, vibration, or deterioration of the metal in the radiator. Most cars have individual types of radiators. For repair service, however, it is possible to use the same tools and materials to repair successfully any make of radiator. The equipment for radiator repair includes:

1. A tank large enough to hold the largest radiators to be repaired.
2. An air compressor.
3. A gas torch for soldering, loosening, or removing damaged sections of the radiator.
4. An iron-topped table for surface work.
5. A pressure gauge reading to at least 8 pounds. (Too great a pressure applied on the radiator will burst the walls.)
6. Acid pot, wire brushes, snips, and pliers.

The job of repairing a radiator is usually a difficult task to one who has not had considerable practical experience. The intricate construction and thin walls make necessary a very high degree of skill in the use of the tools before one may be successful. Except for certain outside leaks, it is not advisable for the general repairman to attempt to overhaul a burst or leaky radiator. He should remove it from the car and send it to a shop which makes a specialty of radiator work.

The use of alkali solutions for cleaning out the radiator will sometimes seal up the leak so that it cannot be located.

Where temporary repairs are necessary, certain non-leak preparations can be used. These preparations should be regarded as temporary and should not be depended upon too much, as the circulation may be impeded and the water caused to overheat.

To test for leaks plug up all ports, lay the radiator in the tank of water, pump up a few pounds (5 or 6) of air pressure, and note the location of the leaks.

When soldering the radiator, all parts must be clean before applying the flux. After closing up a leak, test the radiator again. If no other leaks appear, smooth the soldered places, make a final test, and paint the surface, using a special paint prepared for this purpose.

To avoid the necessity of draining the cooling system to prevent the water from freezing, it is advisable to fill the system with an anti-freeze solution. The simplest and best all-around solution consists of a mixture of alcohol and water.

Since the alcohol in the solution evaporates more rapidly than the water, the percentage of alcohol consequently decreases. If the evap-

orated alcohol is not replaced, the solution will in time lose all of its anti-freeze properties. For this reason, occasionally check the freezing point by measuring the specific gravity of the mixture by means of a hydrometer. If a hydrometer is not available, good results may be obtained by replacing the evaporated solution with 25 per cent water and 75 per cent alcohol. (See p. 493, Part Two.)

Questions.

1. What methods are used for cooling engines that do not use a water-circulating system?
2. Is it a good plan to insert the end of a garden hose in the radiator opening, close up the space with a cloth, and try to force out an obstruction in the drain cock?
3. What kind of water is best for the radiator?
4. What methods are used on certain cars to control the amount of circulation?
5. What is a thermo-syphon cooling system?
6. What causes the water to circulate in the above system?
7. Which requires the larger volume of water, the forced circulation or the thermo-syphon system?

CHAPTER VI

AUTOMOBILE MACHINE SHOP WORK

JOB No. 1

CENTERING AN ARMATURE SHAFT

Operations Necessary to Perform the Job.

1. Mount a three-jawed chuck on lathe.
2. Mount commutator in chuck.
3. Set steady rest.
4. Adjust steady-rest jaws.
5. Mount drill chuck in tail stock.
6. Grip center in drill chuck.
7. Center drill the commutator shaft.
8. Remove commutator shaft from lathe.

Names of Tools to be Reviewed before Performing the Job.

Lathe, three-jawed universal chuck, steady rest.
Drill chuck, center drill.

Description of Operations.

When a commutator shaft revolves between the centers on a lathe, the bearings should run true. If the bearings do not run true, the centers in the shaft may be defective. This defect can be corrected by using a chuck and a steady rest, as shown in Fig. 1*a*. A commutator should never be turned when the shaft does not run true.

FIG. 1*a*.—Recentering a Commutator Shaft.
(Illustration furnished by South Bend Lathe Works.)

A three-jawed universal chuck is preferable because it saves time in truing up the work. When placing the commutator in position, a piece of sheet brass should be inserted between the chuck jaws and the armature shaft so as to prevent defacing the bearings.

The steady rest should be set so that the end of the shaft is about even with the steady-rest jaws. When the jaws are set properly the dead center

will make a small center when pushed against the end of the shaft while the lathe is running. If the center makes a circle on the end of the shaft, it shows that the steady rest is not properly adjusted and it should not be used in this position. After the steady rest has been readjusted, a drill chuck should be inserted into the tail stock and a new center made on the end of the shaft. The steady-rest jaws should not be adjusted too tightly as to do so will score or mar the shaft. A good supply of oil should be maintained on the shaft where it makes contact with the steady-rest jaws.

Questions.

1. How can you prevent the chuck jaws from burring the commutator shaft?
2. How should the steady rest be set?
3. How can the shaft be marred with the steady rest?
4. At what angle are lathe centers turned?

Job No. 2

TURNING A COMMUTATOR

Operations Necessary to Perform the Job.

1. Clean out centers of shaft; recenter, if necessary. (See Job No. 1.)
2. Select and attach proper dog to shaft.
3. Mount driving plate and inspect centers.
4. Adjust work between centers.
5. Set machine to proper speed and feed.
6. Insert and adjust square-nosed cutting tool in tool holder.
7. Start machine and take light cuts until commutator runs true.
8. Polish with fine sandpaper.
9. Remove commutator from lathe.

Tools and Materials Necessary to Peform the Job.

Tools.—Lathe, lathe dog, cutting tool, armature.

Materials.—Sandpaper, oil, sheet brass.

Description of Operations.

When the commutator of a generator or starting motor becomes worn from brush contact, it can be trued up by turning it in a lathe.

To start this operation, oil the live center and adjust the commutator between the lathe centers so that it will turn freely, yet will have no end

play. As stated in Job No. 1, it is very important that the shaft run true in the lathe. If the commutator is turned down when the shaft wobbles, it will run eccentric when installed in the motor or the generator, thus causing the brushes and commutator to wear quickly and to cause trouble.

A sharp-pointed lathe tool should be used, and should be set so that the point does the cutting. This kind of a tool, with a high speed and a fine feed, produces a smooth finish.

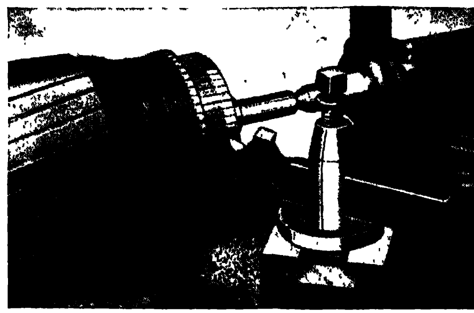


Fig. 2a.—Truing a Commutator.
(Illustration furnished by South Bend Lathe Works)

Precautions.—If the shaft runs "out of true," it may be caused by burred centers, or the shaft itself may be bent. Always use a piece of sheet brass between the lathe dog and the shaft to prevent marring the bearing. Always shut off the automatic feed when turning near the corner, and then feed up to the end of the cut by hand. Sandpaper, *not emery cloth,* should be used for polishing, as the emery from the cloth imbeds itself in the commutator, causing the brushes to wear away, and lodges between the segments, causing short circuits.

Questions.

1. What is the result if the centers do not run true?
2. What is the best type of cutting tool to use when turning a commutator?
3. What effect will polishing with emery cloth have on the brushes and the commutator?
4. What will cause the shaft to run out of true?

Job No. 3

MACHINING A BRONZE BUSHING

Operations Necessary to Perform the Job.

1. Select stock 1 inch longer than sample bushing.
2. Mount chuck on lathe.
3. True up bushing stock in chuck.

4. Insert round-nosed tool in tool holder.
5. Make a "rough turn" to $\frac{1}{32}$ inch oversize.
6. Face one end of stock.
7. Place drill chuck in dead center.
8. Grip center drill in drill chuck and center stock.
9. Select drill $\frac{1}{32}$ inch smaller than diameter of hole through bushing.
10. Fasten boring tool in tool post.
11. Bore and ream to finished size.
12. Make "finish turn" on outside.
13. Cut off bushing to proper length.

Names of Tools and Materials to be Reviewed before Performing the Job.

Lathe, chuck, tool holder, drill chuck, center drill, drills, boring, cutting-off and turning tools, calipers, micrometer, bushing stock.

Description of Operations.

When a ready-made bushing is not available for replacement, a new bushing may be made on the lathe. Select a good grade of bearing bronze. Place a chuck on the lathe and grip the stock, which should be cut about 1 inch longer than the length of the bushing required, so that enough extends out of the chuck for the length of the bushing plus an allowance for facing and cutting off. The bushing should run true in the chuck.

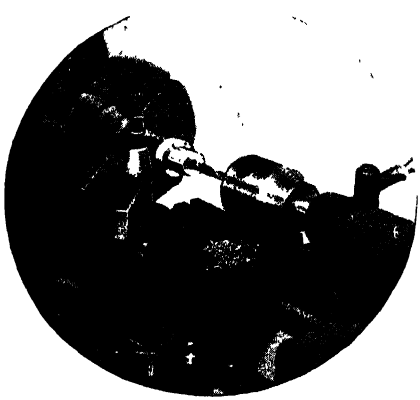


FIG. 3*a*.—Machining a Bronze Bushing. (Illustration furnished by South Bend Lathe Works.)

When the stock has been properly set in the lathe, the cuts should be made. Use a round-nosed tool, turning the outside $\frac{1}{32}$ inch over the finished size and facing the end of the bushing with the same tool. A drill chuck should then be placed in the dead center and a "center" made on the bushing by means of a center drill. This center-drill hole will act as a guide for the larger drill. The operator should select a drill about $\frac{1}{32}$ inch smaller than the desired finished hole and drill to a depth equal to the length of the bushing plus the amount required for cutting off. A boring tool should then be placed in the tool post and the hole bored 0.004 to 0.006 inch

under the size of the finished hole and then reamed to the finished size. The bore should be measured with an inside caliper set to size with an outside micrometer.

To insure a concentric bushing, it is good practice to allow a small amount of metal on the outside, which will later be turned off after the hole or bore is finished.

Questions.

1. Is the bushing finished all over before it is removed from the machine? Why?
2. Why is the stock centered before drilling?
3. How much should be left in the bushing for reaming?
4. How is the bore measured?

Job No. 4

TURNING A SEMI-FINISHED PISTON

Operations Necessary to Perform the Job.

1. Mount adapter on lathe.
2. Attach piston to adapter.
3. Tighten drawbar which holds piston in place.
4. Determine size to which piston is to be turned.
5. Insert square-nosed tool in tool holder.
6. Take light cuts and finish to micrometer size.
7. Turn ring bands.
8. Remove piston from lathe.

Names of Tools to be Reviewed before Performing the Job.

Lathe, adapter, drawbar and pin, cutting tool, micrometers.

Description of Operations.

Pistons $\frac{1}{16}$ to $\frac{3}{32}$ inch oversize can be obtained from the manufacturers when finished pistons are not available. These are called semi-finished pistons because an allowance has been left on the diameter of the piston which can be turned off on a lathe to the desired size.

When turning pistons, an adapter, having a projection on it the same size as the bore of the piston skirt, Fig. 4*a*, should be screwed on the lathe spindle. The adapter centers the piston accurately while turning. To hold the piston on the adapter, a pin should be placed in

the piston pin hole through the edge of the drawbar which passes through the lathe spindle, and tightened with a nut which will hold the piston tightly to the adapter. Care should be taken not to draw the nut too tight as this will distort the piston.

A square-nosed tool with a light drag should be used for turning. Measure the cylinder bore with inside micrometer and determine the finished size to which the piston should be turned.

Cast-iron pistons should be fitted 0.00075 to 0.001 inch per inch smaller in order to allow for clearance and expansion. The top of the piston gets the hottest, therefore it expands more than the skirt.

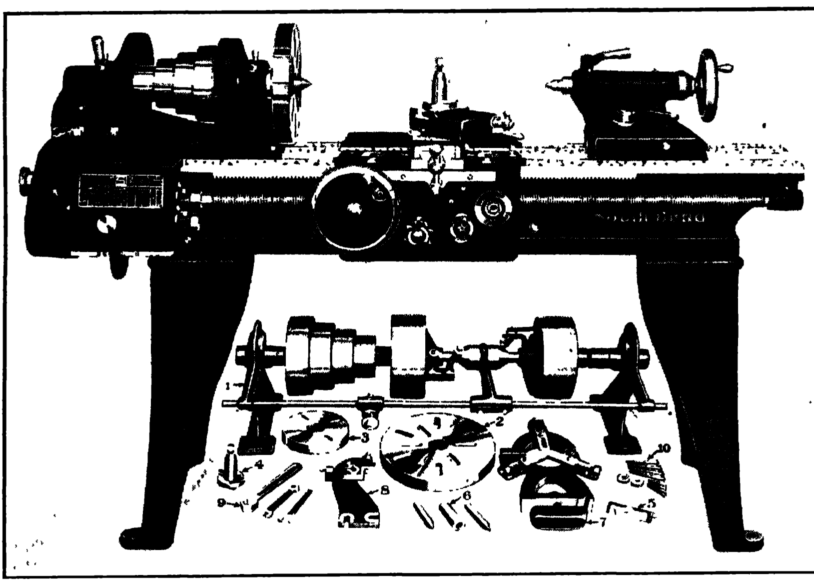


FIG. 4a.—A Lathe for Turning Pistons.
(Illustration furnished by South Bend Lathe Works.)

A clearance of 0.00075 to 0.001 inch, per inch of the diameter of the piston, is necessary between the piston and the cylinder, so as to provide room for expansion when the piston becomes heated.

The top of the piston receives the most heat, therefore more clearance between the piston and the cylinder wall is necessary. The uppermost ring band should have a clearance of 0.004 inch for each inch of cylinder diameter. The second ring band should have a clearance of 0.003 inch per inch of cylinder diameter, and the third ring band a clearance of 0.002 inch per inch of cylinder diameter.

It is poor practice to file or use emery cloth on a piston. It should be turned to the finished size with the lathe tool.

Questions.

1. What are semi-finished pistons?
2. What is the use of the adapter?
3. What is the clearance for a cast-iron piston?
4. Why should top bands be turned smaller?

Job No. 5

FACING A RING-GEAR SET OF A DIFFERENTIAL HOUSING

Operations Necessary to Perform the Job.

1. Remove gears from housing.
2. Clean housings.
3. Assemble housings.
4. Mount on arbor or grip in chuck.
5. Adjust lathe centers.
6. Insert square-nosed tool in tool holder.
7. True up ring-gear seat.
8. File burrs and remove job.
9. Remove lathe dogs and press out arbor if job is carried out by method illustrated in Fig. 5*a*.

Names of Tools to be Reviewed before Performing the Job.

Lathe, arbor, arbor press, lathe dog, cutting tool, chuck, plug center.

Description of Operations.

When a new differential gear is to be fastened to an old differential-gear housing, the ring-gear seat should run true, because the seat governs the trueness of the ring-gear. A ring-gear that runs out of true will cause a " howl " in the differential when working under power. It is impossible to adjust a ring gear and pinion correctly when the differential housing is not true. When preparing the work for facing, the housings should be cleaned and bolted together, the differential gears being omitted. A true shaft having centers in both ends, called an arbor, and fitted to the bore of the housing, should then be pressed into the hole so that the housing will revolve with the arbor, or " true up " in the chuck. In this position a lathe dog is used to turn the arbor on

the centers. The lathe centers should run true and be adjusted so that the work will turn freely and have no end play.

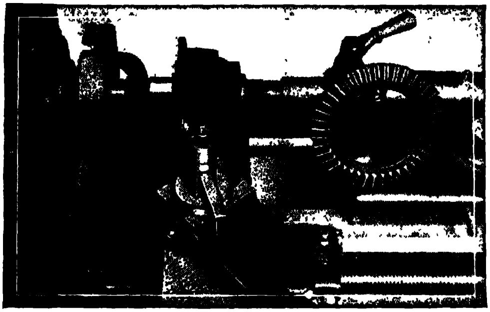


FIG. 5a.—Facing a Ring gear Set on a Lathe. (Illustration furnished by South Bend Lathe Works.)

A small round-nosed tool should be used for facing, so that a filler having a small radius will remain in the corner. A sharp corner tends to weaken the casting. It is good practice to leave a small spot of the old surface showing on the ring-gear seat as a proof mark. The proof mark shows that too much material has not been removed from the gear seat but just enough has been taken off to true it up. In finishing, all burrs should always be filed from sharp corners as they tend to cut the workman's hands when handling.

Questions.

1. Why is it necessary to true up a ring-gear seat?
2. Why should there be a small radius in the corner?
3. How is the work held in the lathe?
4. On the finished job, what proof should be visible that too much material has not been removed?
5. What should be done to all sharp corners?

JOB No. 6

TURNING A FLYWHEEL FOR A STARTER RING GEAR

Operations Necessary to Perform the Job.

1. Clean flywheel.
2. Mount chuck on lathe.
3. Grip flywheel in chuck.
4. True up flywheel.
5. Measure inside diameter of new ring gear and set calipers.
6. Set round-nosed tool in tool holder.
7. Adjust speed and feed.
8. Start lathe and take rough cuts to within $\frac{1}{32}$ inch of finished size.
9. Finish to size, file burrs, and remove wheel from chuck.

Names of Materials and Tools to be Reviewed before Performing the Job.

Lathe, four-jawed chuck, tool holder, round-nosed tool, new ring gear.

Scale, calipers, blow torch, tongs.

Description of Operations.

The constant use of a starting motor often chips and wears the teeth of the flywheel. If the teeth are cut on the flywheel, this defect may be

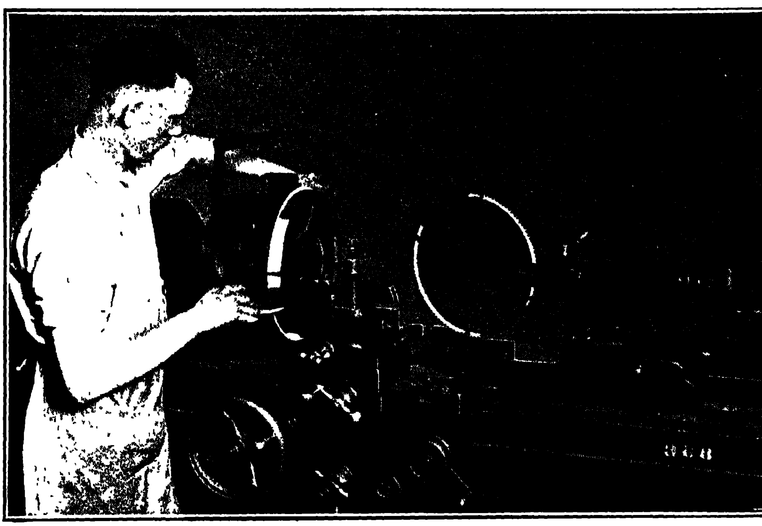


FIG. 6a.—Turning a Flywheel for a Starter Ring Gear.
(Illustration furnished by South Bend Lathe Works.)

remedied by turning off the old teeth and shrinking on a new ring gear. To perform this job, clean the flywheel, mount a four-jawed independent chuck on the lathe, and adjust the flywheel in the chuck, making it run true.

Before taking a cut, measure the inside diameter of the ring gear. As a check, the repairman will find, stamped on the face of the new gear, the size to which the flywheel should be turned. When turning off the old teeth, use a round-nosed tool and a slow cutting speed. Rough-turn the flywheel to within $\frac{1}{32}$ inch of the finished diameter. Care should be taken to turn accurately to the size which is stamped on the

face of the ring gear. When the necessary cuts have been taken, file off all burrs and remove the flywheel from the chuck.

To shrink the ring gear on the flywheel, expand the gear by heating it evenly to a temperature of about 400°, which will not darken or discolor the metal. The ring gear should then be placed on the flywheel in the proper position and allowed to cool. If this operation has been performed correctly, it will not be necessary to anchor the ring gear to the flywheel with screws.

Questions.

1. What causes the teeth to break off a flywheel?
2. How is the finished diameter determined?
3. How is the flywheel held in the lathe?

Job No. 7

REGRINDING A CYLINDER

Operations Necessary to Perform the Job.

1. Clean cylinder.
2. Remove burrs from face that is to be attached to machine.
3. Fasten cylinder to machine.
4. Measure bores for size, with micrometer.
5. Set machine to grind cylinder with largest bore.
6. Proceed to grind remaining cylinders in order of decreasing size.
7. Remove cylinders from grinding machine.
8. Clean all cylinders thoroughly.

Names of Tools to be Reviewed before Performing the Job.

Cylinder grinder, micrometer, cylinder gauge, file, pistons.

Description of Operations.

After an engine has been in operation for some time and the cylinders have become worn, it is good practice to true up the cylinders by grinding. To perform this job it is necessary to remove the engine and dismantle all the parts. The cylinders must be cleaned before attempting to grind the bores. The face that is to be attached to the machine should be free from dirt or burrs, and the cylinder fastened to the grinding machine with clamps, as shown in Fig. 7*a*.

As some cylinders wear faster than others, it is necessary to measure all the bores and select the one having the largest bore and grind it first.

The one having the next largest bore should be second, and so on to the smallest.

When truing up the cylinder, for grinding, the spindle arm to which the grinding wheel is attached should revolve, and the cylinder should be adjusted so that the wheel will grind lightly around the entire circumference of the bore at the center or half-way through the bore. The size to grind the bore is determined by the pistons available. If semi-turned pistons are to be used, the size of the holes is not so important, but they must be the same diameter in all cylinders.

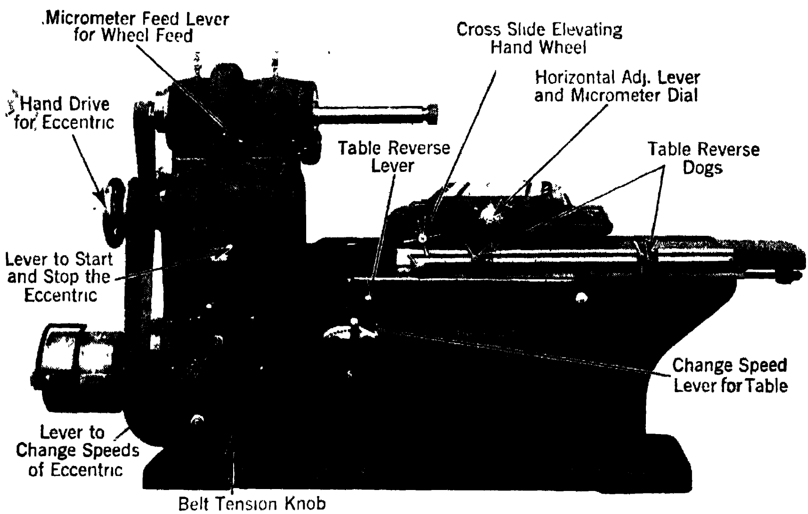


FIG. 7a.—Cylinder Grinder. (Heald.)

Heat generated while grinding the cylinder causes the cylinder to expand. Allowances must therefore be made to compensate for the expansion when the cylinder cools.

The cylinder should be thoroughly cleaned when the work is finished, as any particle of dirt left may be carried to the bearings by the oil, thus spoiling the running surfaces.

Questions.

1. What causes the cylinder to wear?
2. How can a worn cylinder be reconditioned?
3. How is the bore "trued up" for grinding?
4. Which cylinder should be ground first?
5. What makes the cylinder expand while being ground?

PART TWO

GAS-ENGINE MECHANICS AS APPLIED TO AUTOMOTIVE EQUIPMENT

INTRODUCTION

Theory and Practice in Automotive Repair.—As stated in the introduction to Part One, the author has recognized the several types of automotive repairmen and *has limited the subject-matter in this volume to that which a general repairman needs to know.* Much care has been taken to eliminate from the text advanced scientific and mathematical theory which, while of use and interest to the man who designs automotive equipment, is of little or no practical use to the general repairman, or to the owner who takes care of his own car.

Throughout the text it is assumed that the repairman has to do only with the repair, upkeep, and operation of a finished machine. Fifteen years ago the design of automobiles was less perfect; consequently, it often became necessary for the repairman to strengthen and rebuild parts which to-day need only to be replaced. Many parts are now standardized and the improvement in the construction of electrical and fuel equipment likewise has reduced to a great extent the troubles of the owner and the repairman.

The Engineer vs. the Mechanic.—It has been the job of the engineer to plan and to perfect the many improvements which have transformed the car of yesterday from a creature of uncertain behavior to one of the most perfect machines of the present day. It has been his job to study its efficiency and to improve the quality of materials to be used in its construction and operation. On the other hand, the repairman has a job of no less responsibility. It is his duty to see that the investment of the owner becomes an asset and not a liability. It is his duty to keep the car in good repair and operating condition. To do this he must know how to locate troubles and how to diagnose their causes; how to take down and reassemble all parts; and how to make replacements and readjustments. To a much less degree than the machinist he has occasion to use machine tools and machine-tool equipment in making and shaping parts.

An engineer takes great pride in completing a well-designed structure. His reputation depends upon the accuracy of his calculations and upon his previous practical experience. In a similar manner the automotive repairman should work to develop a reputation for skill, knowledge,

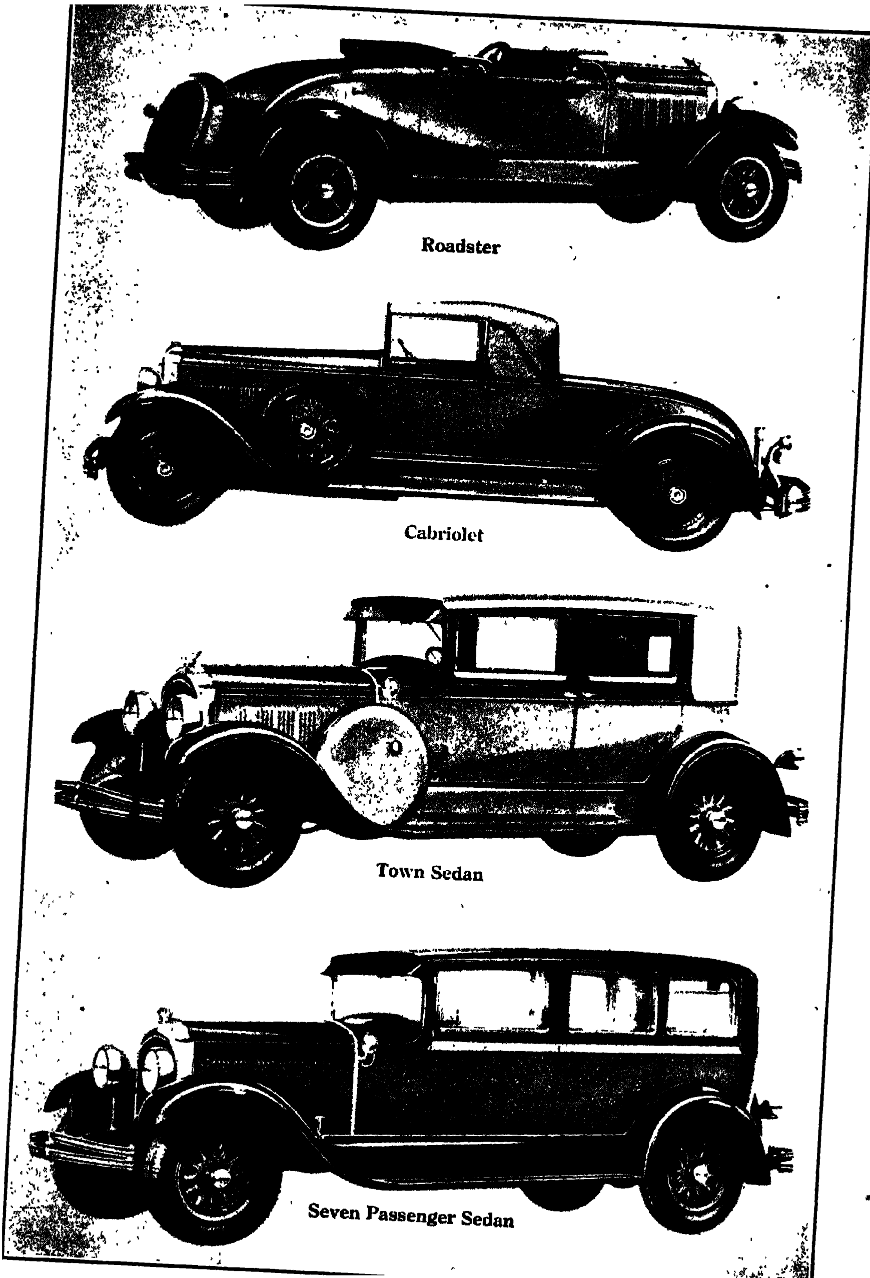


Fig. 1.—Roadster, Cabriolet, Touring or Phaeton and Sedan.

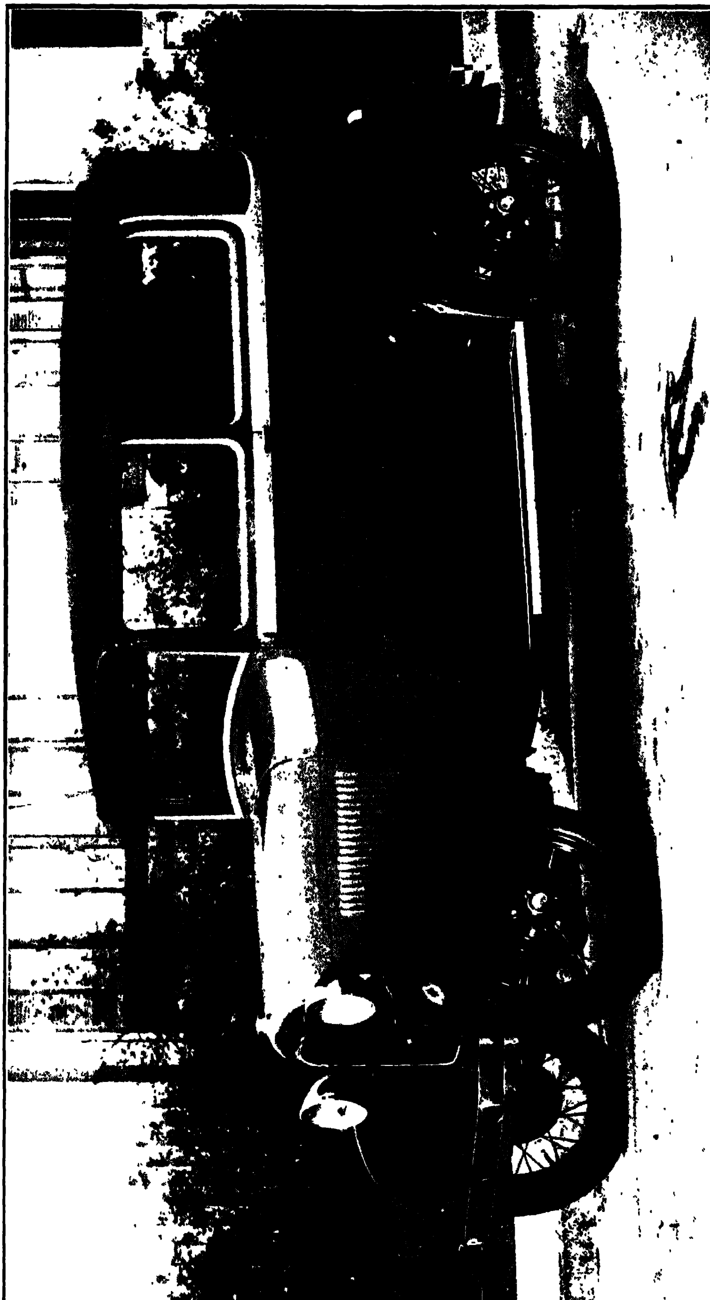


Fig. 2.—Model A Ford "Tudor" Sedan.

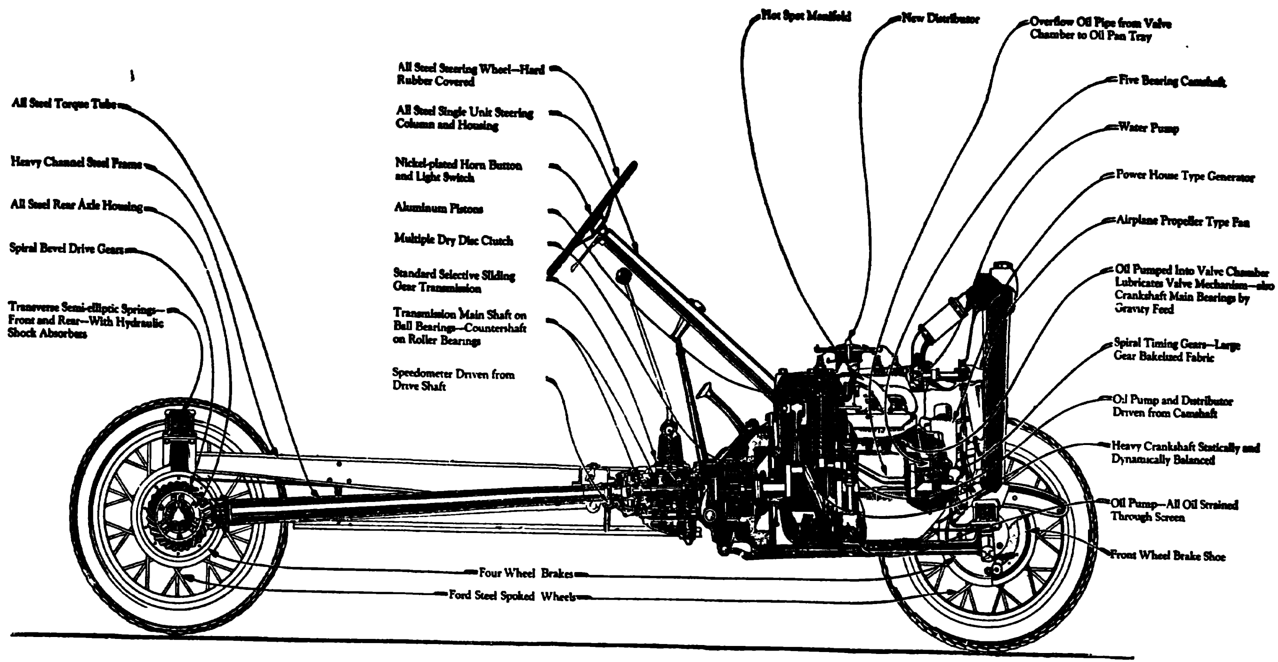


FIG. 3.—Cross Section of Model A Ford Chassis.

and honesty in giving service to his customers. To give this service requires a thorough knowledge of repair jobs, an understanding of the theory of operation of gas engines, and an ability, gained largely through experience, to locate and to analyze troubles.

In Part One most of the jobs which come to the general repair shop have been discussed from the standpoint of making repairs. Part Two is an *elementary study of the theory of gas-engine mechanics, of electricity as applied to the automobile, of lubrication, and of fuels and carburetion.* Each subject has been treated from the standpoint of the amount of theory the repairman or the owner needs to know in order to keep the car in good running condition and in good repair.

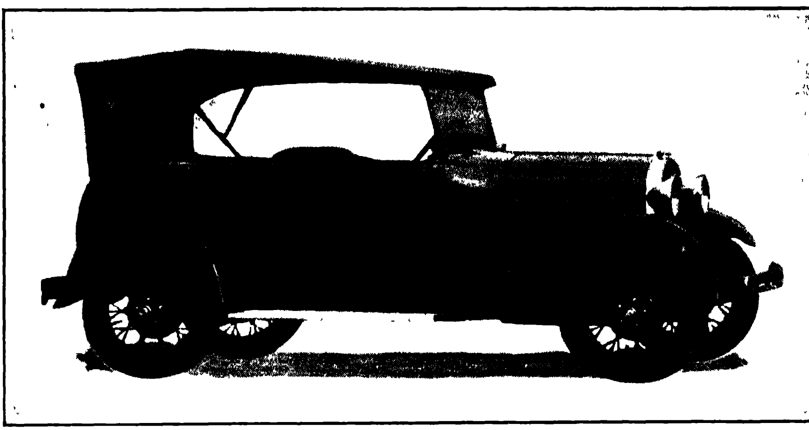


FIG. 4.—Model A Ford Touring Car.

Types of Automobiles.—There are five principal types of vehicles known as automobiles: (1) the gas-driven, (2) the steam-driven, (3) the electric-driven passenger car, (4) the truck, either gas- or electric-driven and (5) the bus, either gas- or gas-electric-driven.

By far the larger percentage of cars are of the first, or gas-driven, type; therefore, this book, in the following pages, refers only to this type. While few specific references are made to truck operation and repair, most of the theory and repair work relating to the passenger car is equally applicable to the gas-driven truck.

Cars may be further classified, as to construction, into a large variety of types. The nomenclature of the Society of Automotive Engineers includes the following types:

Roadster.—An open car seating two or four. It may have additional seats in a rear deck. (Fig. 1.)

Cabriolet.—Seats two or four. It has a folding top and full-height doors with disappearing panels of glass. It may have additional seats in the rear deck. (Fig. 1.)

Coupe.—An inside-operated, enclosed car seating two or three.

Touring Car or Phaeton.—An open car seating four or more, with direct entrance to the tonneau. (Fig. 1.)

Convertible Touring Car.—A touring car with a folding top and disappearing or removable glass sides.

Sedan.—A closed car seating four or more all in one compartment, (Fig. 1.)

Limousine.—A closed car seating three to five inside, with driver's seat outside, covered with a top.

Berline.—A limousine having the driver's seat entirely enclosed.

Brougham.—A limousine with no roof over the driver's seat.

Landaulet.—A closed car with folding top, seats for three or more inside, and driver's seat outside.

CHAPTER VII

THE CHASSIS AND ITS CONSTRUCTION

In the past much more attention has been given to engine work and trouble shooting than to the care and repair of the chassis. Manufacturers are attempting in every way possible to perfect the construction of the rear assemblies, the transmission, and the bearings in order to strengthen weak construction and to increase the efficiency of the car. Even though the engine is adjusted properly and is in good operating condition, the chassis likewise must be in good working order or the owner will have trouble.

The chassis is the frame and all of the working parts of the automobile after the body has been removed, as shown in Fig. 5. For convenience in arrangement, engine work has been separated from chassis work and will be discussed in the following chapter. The chassis is the base or foundation upon which the motive power and bodies of various types are mounted. The purpose for which the car is to be used determines the design of the chassis. In its construction all members must be designed to support a given load with a satisfactory safety margin. The very best metals must be used in order to reduce surplus weight. Braces and stays must be placed where the strain is the greatest. Each member must be subjected to many different practical tests before it can be standardized.

Frame Construction.—In the beginning frames were made largely of wood and bolted together. The modern frame is constructed of steel with supporting-side members, cross members, and gussets, all riveted together. Some frames are designed with the rear end raised; many are straight; while others shorten the rear frame through the use of the cantilever-type spring. Whatever shapes are used, the functions of the frame are to provide a rigid support for mounting chassis units and to support the body, and these functions determine its construction.

Some automobiles have sub-frames consisting of cross and longitudinal members for supporting the engine, transmission, and other units. At present the tendency is to simplify the construction and mount the different units directly on the frame.

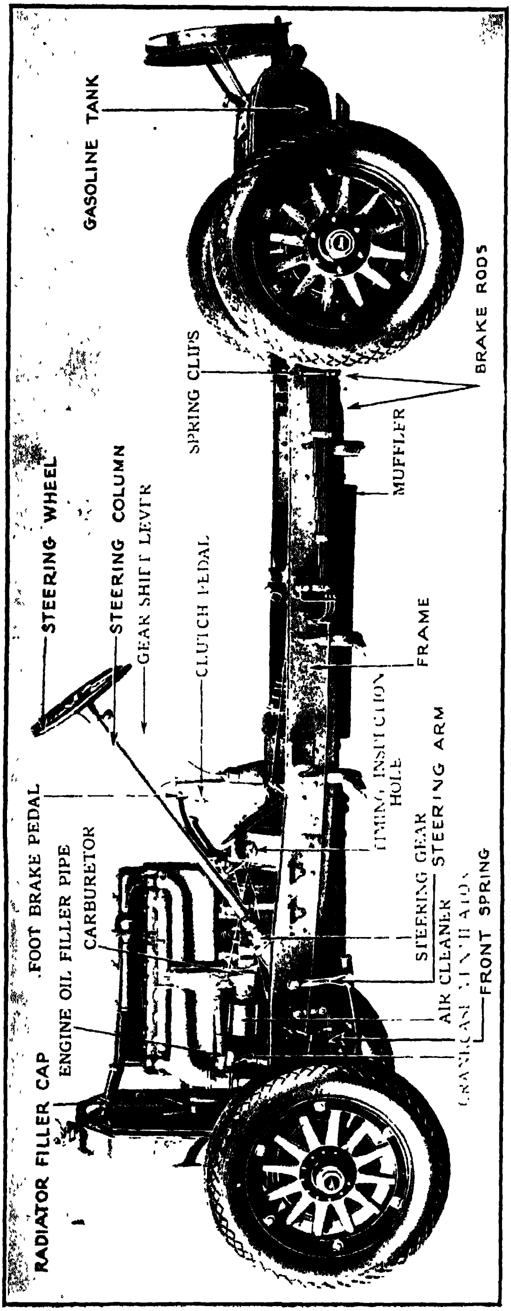


FIG. 5.—Left Side View of Chassis. (Buick, 1928.)

From the standpoint of the repairman the frame is supposed to be well designed and to require little attention except to see that it retains its true shape and that the rivets are kept tight. Job No. 1, Chapter I, covers the details of frame repair.

Figure 5, p. 344, shows a typical chassis. The frame is supported in the rear by cantilever springs. The frame is curved or "kicked up" over the rear axle to provide greater clearance. Figure 7 shows a section of the Stutz car cut vertically through the center of the longitudinal axis. This cut affords a particularly good opportunity to study the relation of the engine to the transmission, the universals, the drive shaft, and the differential.

The power which originates in the cylinders due to the burning gases produces a pressure or force upon the pistons which is, in turn, transmitted to the connecting rods and crank shaft to be trans-

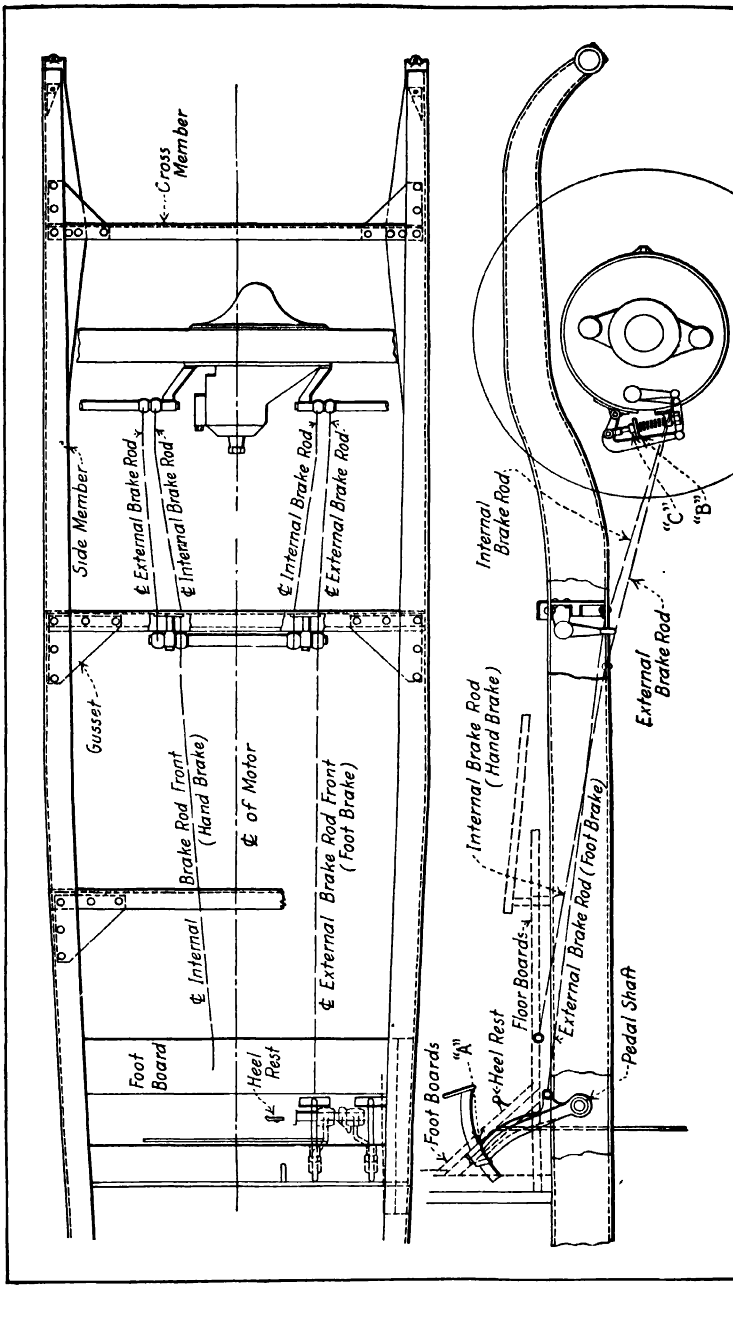


FIG. 6.—Frame Construction, Showing Top and Side Views.

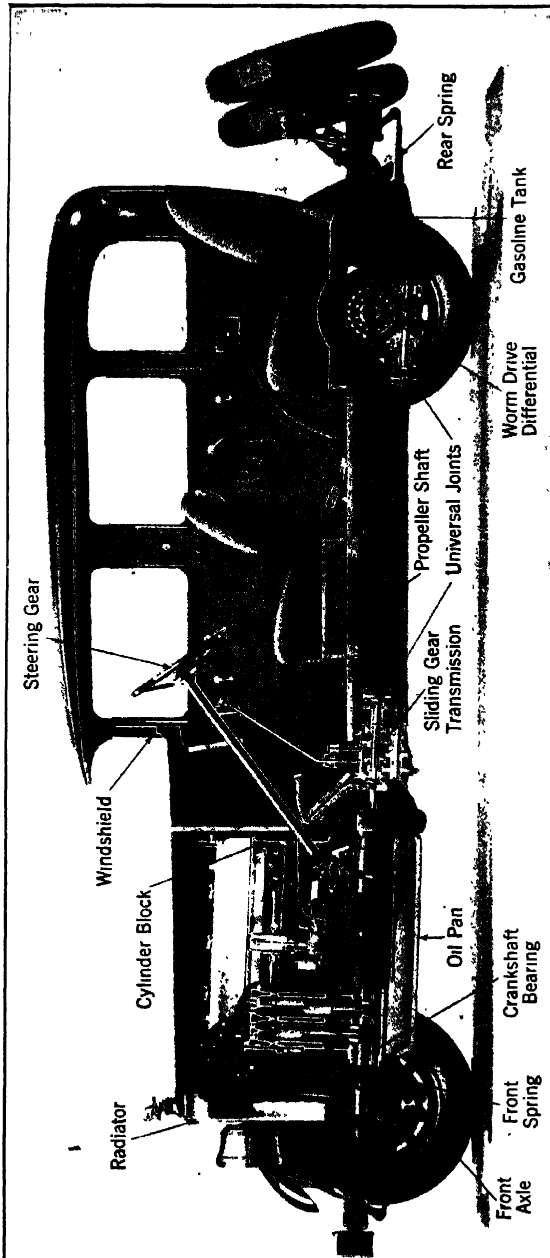


FIG. 7.—Cross-section of Car. (Stutz "8.")

formed into a rotary motion. In this form it is conveyed through the clutch, the transmission, the shaft, and the differential to the rear wheels. Each of these moving parts consumes a certain amount of this power; therefore, the total delivered to the rear wheel is less than that produced in the cylinders. The efficiency of any machine is equal to the per cent of work delivered as compared with the work consumed, or Efficiency $= \frac{\text{Output}}{\text{Input}}$.

In all machinery, friction is the principal cause of loss of power. For example, if the efficiency of the engine is 75 per cent, it can only deliver to the transmission 75 per cent of the effort it has re-

ceived. If the efficiency of the transmission is 80 per cent, it is unable to deliver the full amount received. Since it receives but 75 per cent of the original power developed by the explosion of fuel, it really delivers 80 per cent of the 75 per cent, or only 60 per cent of the original power consumed in the cylinders. Hence, the loss in each unit reduces the ultimate power applied in doing useful work.

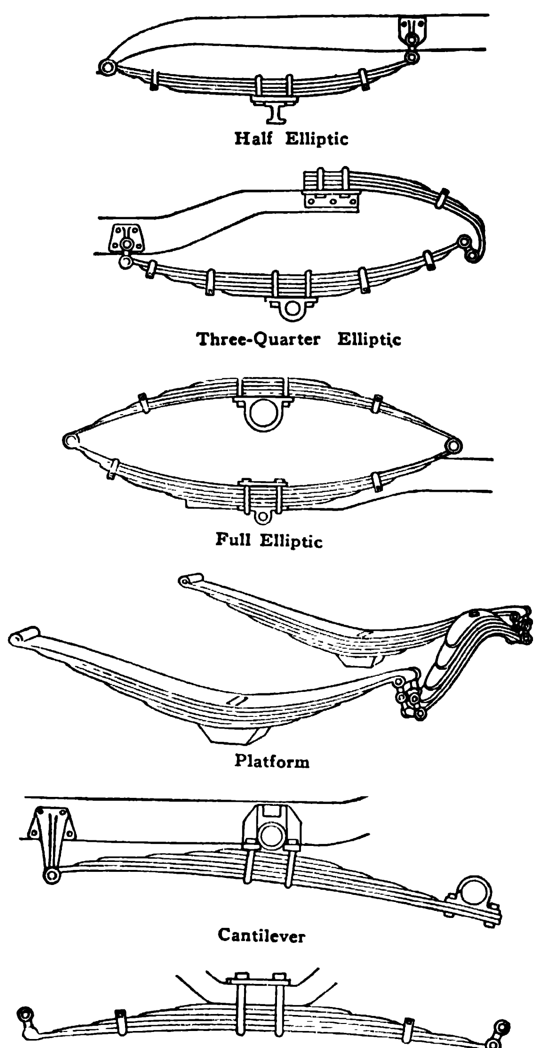


FIG 8.—Types of Body Springs.

To overcome, as far as possible, this loss of power is the ambition of the manufacturer. The frame is designed to reduce undue strains on moving parts. The "three-point" suspension and unit power plant each have been used to eliminate friction due to strains. Bearings have been perfected so that practically all bearing surfaces rely upon roller or ball bearings for their contact. Figure 158, p. 479, shows that 8.5 per cent of the total cost of fuel is lost in overcoming friction in the engine and transmission.

When one considers the number of moving parts and the rough usage accorded an automobile, this low percentage of loss is a great credit to the manufacturer. The repairman must be constantly on guard to prevent additional loss of power through frame alignment or bad bearing

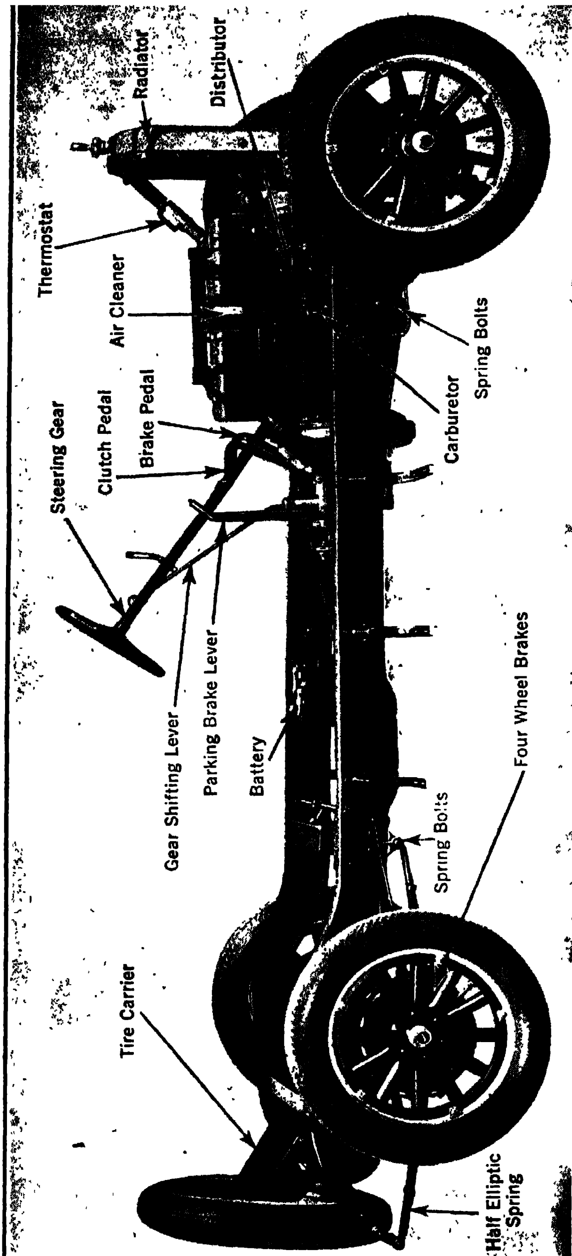


FIG. 9.—Chassis Using Semi-elliptic Spring. (Oldsmobile.)

conditions. In the same figure referred to above, the power of the car under normal conditions is reduced to only 12.5 per cent of the total fuel value, hence an increase of 3 per cent in the friction would reduce the available power by almost one-fourth.

Springs. — Frame design is dependent upon the type of springs to be used. In Fig. 8 the different types of springs are shown. Figure 9 shows a chassis using the semi-elliptic spring to support the frame.

The repairman is much less concerned about the type of springs used on the car than he is about the condition of the springs. All springs need constant care to maintain their

efficiency. It is a common error to suppose that when a spring breaks, upon the car's plunging into a deep hole, that the breakage is caused by the shock coming from the bearing down of the load above the wheels. Usually the breakage is caused, not on the downward movement of the spring but on the rebound. When the load plunges down, the shock is borne by all leaves simultaneously, whereas the force of the rebound is taken up by the leaves singly, one after the other, and for that reason it becomes more emphasized when the spring clips are loosened.

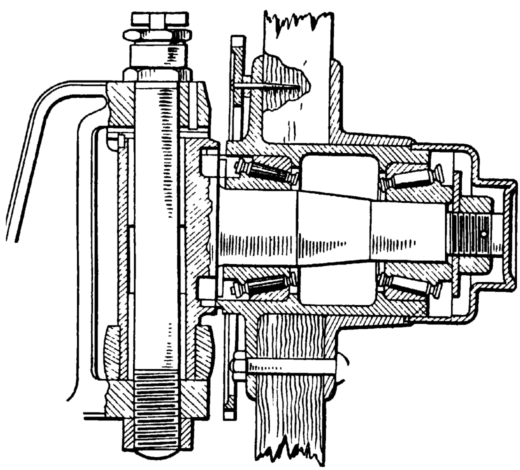


FIG. 10.—Elliott-type Front Axle.

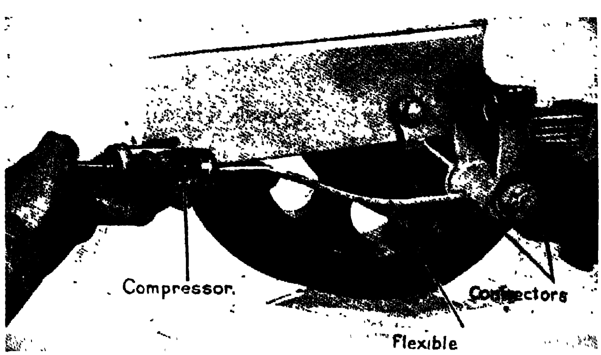


FIG. 11.—Application of the Alemite Gun.

Spring breakage is frequently due to faulty construction. Most breaks occur at the middle where the tie bolt passes through the leaf. Some springs are now made without tie bolts, the same effect being pro-

duced by setting a portion of the metal downward with a punch or by a curved arch which fits over the leaf below.

Practically all springs are now provided with oil or grease fittings at the hanger or shackle, as shown in Figs. 2*b* and 2*c* on page 12. The method illustrated in Fig. 2*b* is called the Alemite system. Every car using this system is equipped with an Alemite gun which provides 500 to 1000 pounds pressure. Under this pressure, grease is forced through the fitting to the place where it is required. Figure 11 illustrates how the Alemite gun is applied.

FIG. 12.—The Zerk Oiling System.

Another method of chassis lubrication is the forcing of oil, by pressure created with an oil gun, to the desired parts. Figure 12 shows this method of lubrication, which is called the Zerk system.

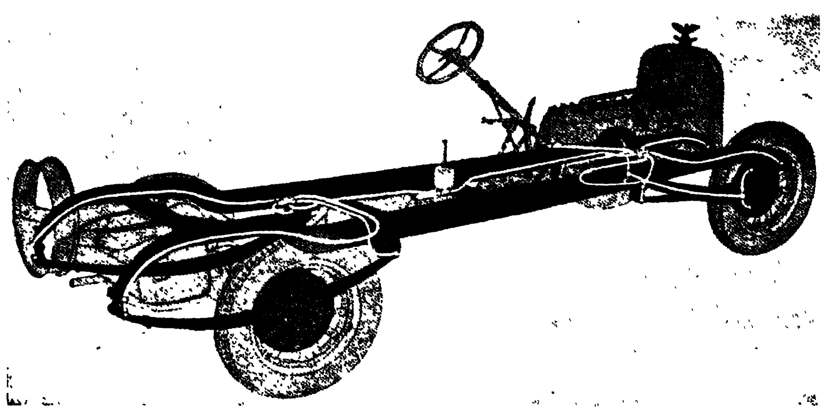


FIG. 13.—The "One-shot" Lubrication System.

A number of cars are equipped with what is called the one-shot lubrication system, as illustrated in Fig. 13. Under this system the complete chassis is lubricated by the one operation of stepping on a plunger located near the driver's seat. This plunger forces oil through copper tubing to all parts that require lubrication. When this system is used the forcing of oil throughout the chassis should be done once a day.

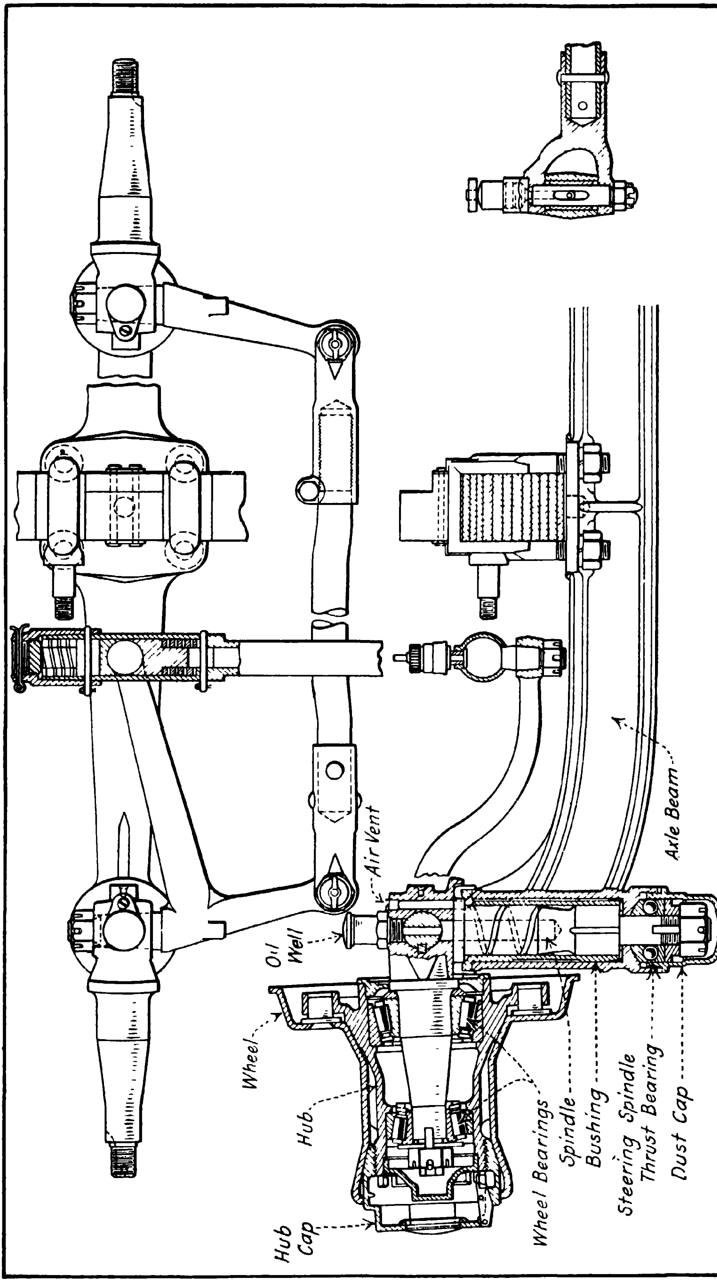


Fig. 14.—Front Axle Hub and Spindle, Lemoine Type. (Marmon.)

In many cases, in addition to the load carried by the rear springs, they must withstand all the driving thrust, torque, and braking stress. If a rear spring is broken no attempt should be made to drive the car until it has been provided with a new spring. Serious damage may result to the rear-axle assembly if this caution is not observed.

In America springs are standardized. Sizes are known by the width in inches and by the length in inches. Five sizes, $1\frac{1}{2}$ to $2\frac{1}{2}$ inches, by $\frac{1}{4}$ inch difference in each, are used on passenger cars.

Front Axles.—The purpose of the front axle is to provide a support for the front end of the car. In general, five principal types are used. the Elliott and the Limoine, together with their modifications, are the most common. Figure 3*a*, p. 14, illustrates a very common type of the Elliott axle. In this construction the load is supported on the upper bearing. In the reversed Elliott the jaws are reversed so that the load is supported on the lower bearing.

The front axle (Fig. 10), is of the Elliott type, which permits the use of two bearings for the steering knuckle pin in the axle end, where such bearings can be of ample size. As will be noted in the diagram, the steering knuckle pin has plain bearings and plain steel thrust washers, while the wheels rotate on tapered roller bearings. The axle itself is of an I-beam section of large dimensions and is a one-piece forging, heat treated. The steering levers are placed back of the axle and are connected to the steering knuckles at the bottom. The tie rod connecting these steering levers is placed behind the axle. The connection to the steering gear, called the drag link, is on the left side and consists of a stout tube with ball joints at each end. These work on hardened surfaces with springs back of them to take up all wear.

Steering Mechanism.—The steering mechanism now used on all types of cars is the result of an invention of Ackerman. It takes the place of the so-called "fifth wheel" which is used on all horse-drawn vehicles. In the latter type, both wheels retain the same relative position to the front axle, while in the former or Ackerman device the wheels are pivoted on each end of the axle and are connected to a steering device by the steering knuckle, the tie rod, and drag link. In the horse-drawn vehicle the whole front axle pivots about the king bolt through the center of the frame and axle. As the turning action is supplied by the horses but little effort has been made to improve and perfect this mechanism.

It is desirable, on the other hand, to make an automobile which will respond to a slight touch of the driver's hand on the steering wheel. One of the chief difficulties to be overcome was to construct the steering knuckle so that the pivot pin would be directly over the point of support

between the tire and the ground. Otherwise, when the wheel was turned it would describe an arc of a circle with the point of support forming the circumference about the pivot as the center. This trouble was partly overcome by designing a close construction between the hub and the pivot and by giving the wheel sufficient " camber " (see Fig. 8*a*, p. 25, Chassis Work) to accomplish the rest.

The mechanical motion which changes the position of the front wheels is produced by the steering device. Several types of steering gears—such as the worm and gear, split nut, cam and lever, planetary and worm and sector—are in common use. Some of these are illustrated in Job No. 9, in the chapter on Chassis Work. The general forms should be studied by the repairman in order that he may thoroughly familiarize himself with the types used on different makes of automobiles.

In designing steering gears two main objectives are to be attained: first, a non-reversible gear which, while permitting easy operation by the operator, will not reverse for every road obstacle struck by the wheel; and, second, the retention of sufficient flexibility to prevent injury to the mechanism when road obstacles are met.

Some types are known as non-reversible. These are found in several forms on most high-priced cars. In some cars the gear is a full gear while in others it is a sector. The former has an advantage in that its position can be changed, thereby reducing the lost motion due to wear between the gear teeth and the worm threads.

The repairman, as a rule, is less concerned with the type than with the means which have been provided for making adjustments to take up the lost motion. When these adjustments are made care must be taken not to set the gear too tight, as a certain amount of play is needed.

Rear Axles.—The rear axle consists principally of five parts: (1) the pinion shaft, which is connected to the propeller shaft by the universal joint; (2) the beveled drive pinion, which is keyed solidly to the pinion shaft so that it turns with it; (3) the beveled drive gear, which is meshed with the pinion and turns at right angles to it; (4) the differential, the case on which the gear is mounted; and (5) the axle shafts, which connect the differential with the rear wheels.

The selection of types of rear axles in any car is made on the basis of the cost of manufacture and the cost of repair. Figures 10*a*, *b*, *c*, and *d*, Job No. 10, in the chapter on Chassis Work, illustrate the four principal types of rear axles, classified as to the method devised for carrying the load and for transmitting the driving power to the rear wheel.

From a theoretical point of view the *full-floating type* (Fig. 10*d*, page 38) is ideal. The axle does not support any part of the load and has only

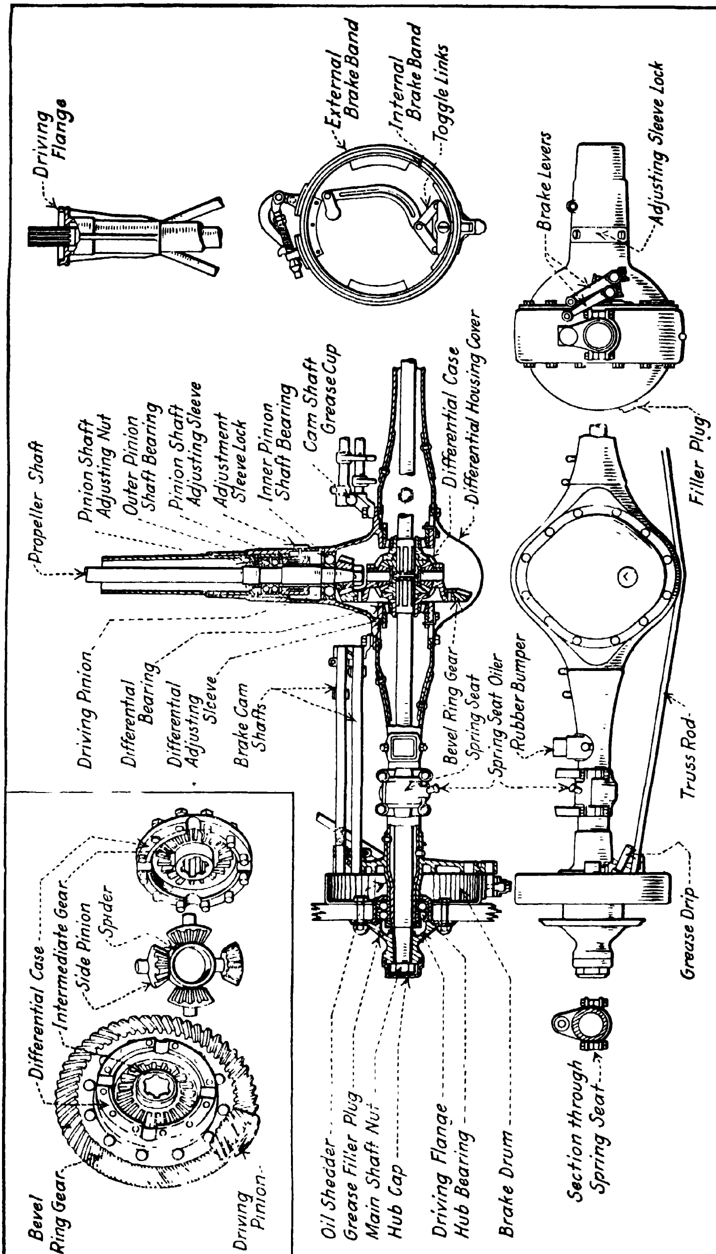


Fig. 15.—Rear-axle Assembly. (Buick.)

the driving torque to transmit to the wheel. It may be removed without disturbing the wheel, but serious difficulties arise when the rear wheel is subjected to a strain severe enough to bend the prolonged end of the axle housing upon which the wheel bearings are placed. In this case the wheel and axle housing must be removed. The housing should be

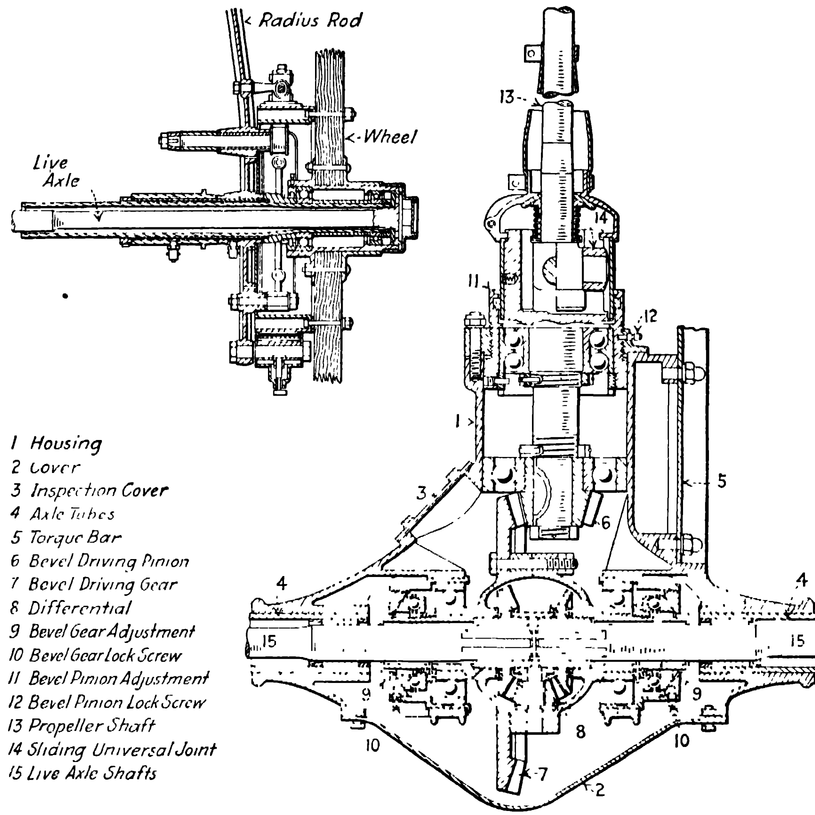


FIG. 16.—Rear Axle and Propeller Shaft. (Full-floating, Locomobile.)

straightened if possible; if not, a new housing becomes necessary. The cost of repairs then becomes much greater for this than for other types.

To overcome this disadvantage the *three-quarters floating* type (Fig. 15, page 354) has been devised. Experience indicates that this construction gives a maximum degree of service with a minimum amount of cost for repairs. Although the wheel bearings are supported on the housing, the danger of injury to the end of the housing from undue strain

on a wheel is considerably lessened by shortening the housing prolongation. The shaft is keyed to the hub and receives most of the bending stress supported by the axle itself instead of being supported on an extension of the axle housing.

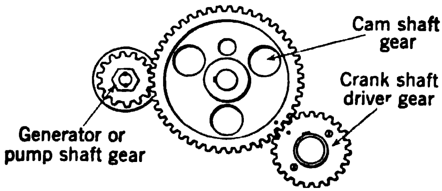


FIG. 17.—Spur Timing Gears.

The semi-floating rear axle (Fig. 10*b*, page 36) is the most popular type used today. In this construction the axle must support the load and transmit the turning torque to the wheel.

Figure 10*a*, page 35, shows the simple *live rear axle* which differs from the semi-floating type in that the inner bearing at the differential end is supported by the axle itself instead of being supported on an extension of the differential case. The live axle supports the full load at the wheel and delivers the full torque, besides withstanding all the bending stresses. Only lighter cars are now equipped with this type, the Model T Ford being the best illustration. Some of the disadvantages of the live rear axle are less efficiency due to greater wear in the bearings and greater difficulty in removing the axle from the rear assembly. To replace a live axle the entire rear assembly must be removed and taken down.

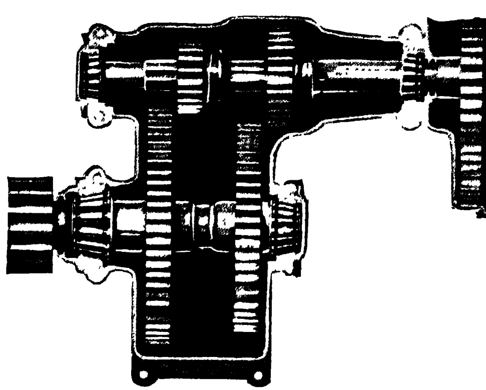


FIG. 18.—Spur Gears. Transmission.

Gear Principles.—While the earlier power systems depended entirely upon the friction between two rolling surfaces as a means of transmitting power from one moving part to another, gear teeth were soon developed as a more satisfactory method. Two gears represent the mechanical principle of the wheel and axle, and the relative speeds of each depend upon the relative number of teeth in the two gears. A small driving gear will produce fewer revolutions when in mesh with a larger driven gear having more teeth, and the reverse condition is equally true.

Several different types of gears are in common use. These include

spur gears, *bevel gears*, and *worm gears*. Figures 17 to 22, inclusive, illustrate these types. Each of these types is used on modern cars and may be found in transmissions, timing gears, differentials, and steering mechanisms. Gears are employed to transmit power, to change the relative revolutions per minute (r.p.m.) of the moving parts, and to change the direction of a propelling force. Whenever an increased number of r.p.m. are obtained through the use of a gear mechanism, a corresponding loss of force or torque results in the same ratio; and in the same way a decrease in the r.p.m. causes a proportional increase in the propelling force. Each moving part in a power-transmitting system causes a loss in power. No machine has or can be invented which delivers 100 per cent of the power received. Whenever a driving torque is transmitted from one gear to another a loss occurs. Each moving part must be considered as a separate unit machine. Each has its own efficiency factor. A gradual loss of power occurs as the driving force is transmitted from the engine to the transmission, then through the universals and drive shafts to the gears in the differential housing.

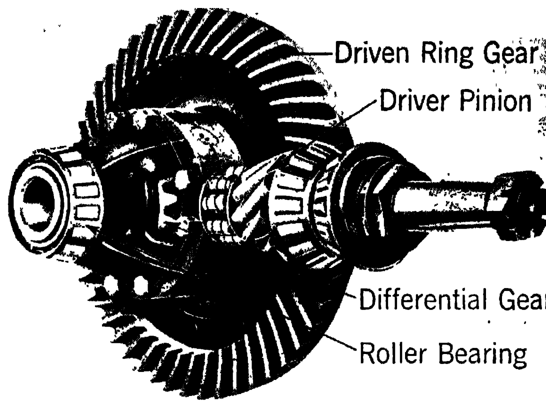


FIG. 19.—Bevel Gears—Rear Axle.

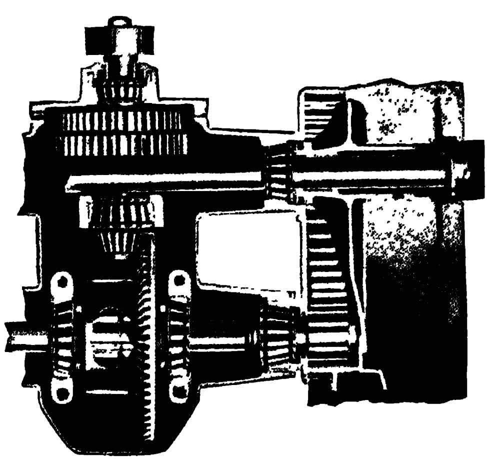


FIG. 20.—Bevel Gears—Tractor.

The power of the engine, instead of being delivered from the beveled ring gear directly to the two axle shafts, is transmitted through the

differential (Fig. 23). The purpose of the differential is to permit one wheel to turn faster than the other when turning corners and when driving over uneven road surfaces. It is evident that the outer wheel when

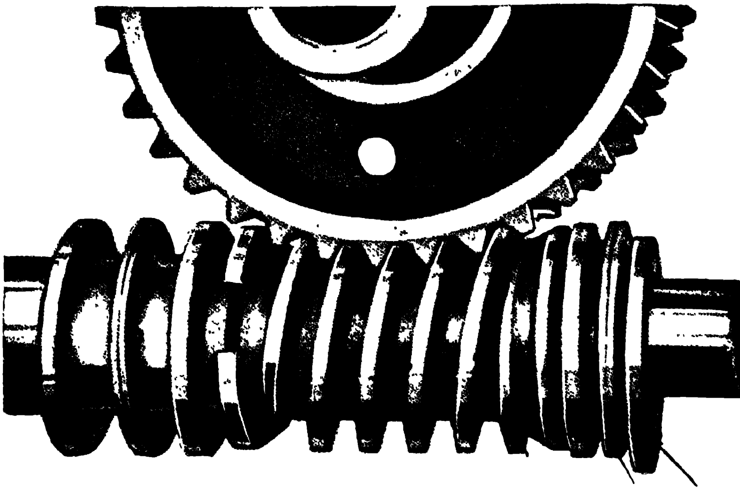


FIG. 21.—Worm Gear Steering Mechanism.

rounding corners has a greater distance to travel than the inner in order to cover the curve. Hence, if there is to be no dragging or slipping of wheels the outer wheel must turn faster than the inner. The differential provides for this equalization and, in addition, provides a means of equalizing the power delivered to the wheels regardless of their relative speeds.

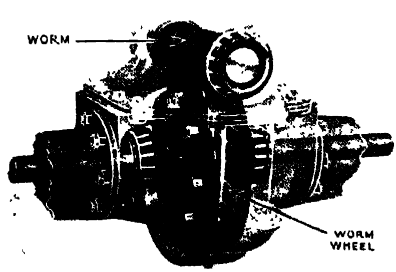


FIG. 22.—Worm-and-Gear Driven Rear Axle.

The drive pinion (Fig. 19) is smaller in diameter than the ring gear and has fewer teeth. This difference in the number of teeth determines what is called the gear ratio of the rear axle. If, for example, the drive pinion has twelve teeth and the ring gear forty-eight, it is apparent that it will require four revolutions of the drive pinion to accomplish one revolution of the ring gear. The gear ratio in this instance is four to one. This means that the crank shaft revolves four times as fast as the rear wheels. All cars are designed for a reduction in gear ratio in order that

the best working speed of the engine may be adjusted to the most suitable speed for rear wheels.

In addition to transmitting power and to changing the relative speed, spur gears are sometimes used to change the direction of rotation, the driven gear always revolving in an opposite direction from the driver.

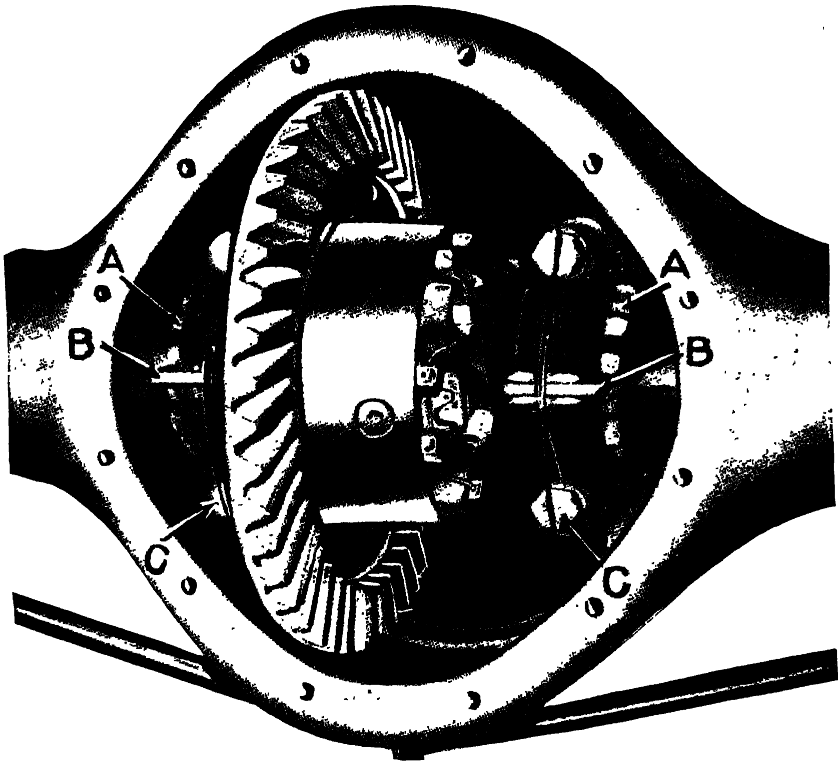


FIG. 23.—Differential Assembled.

Differential Gear.—The large main bevel drive gear (Fig. 24) is bolted to the differential case, which carries the differential spider and on which are mounted the four differential pinions. To the right and left are the two differential gears, each meshing with all four pinions and having splined hollow centers into which the right and left axle shafts fit. Normally, this whole mechanism turns as a unit so that each wheel travels at exactly the same speed as the bevel gear, but when rounding a corner the differential action takes place. If one jacks up both rear wheels, keeps the bevel gear from turning, and turns the left wheel forward, the right wheel will turn backward. This is because the left dif-

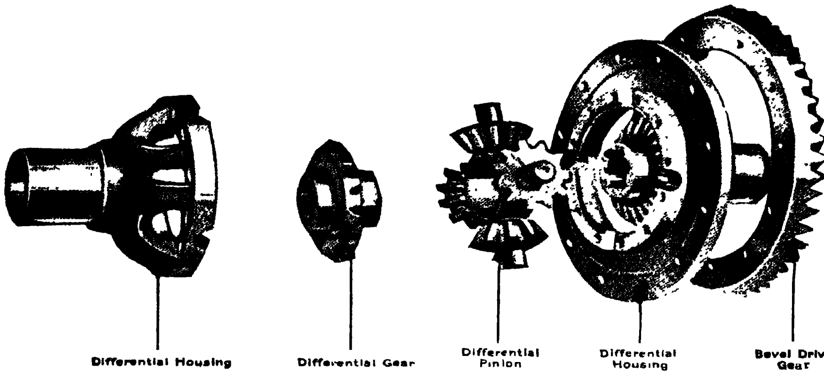


FIG. 24.—Differential Parts—Beveled Gear Type.

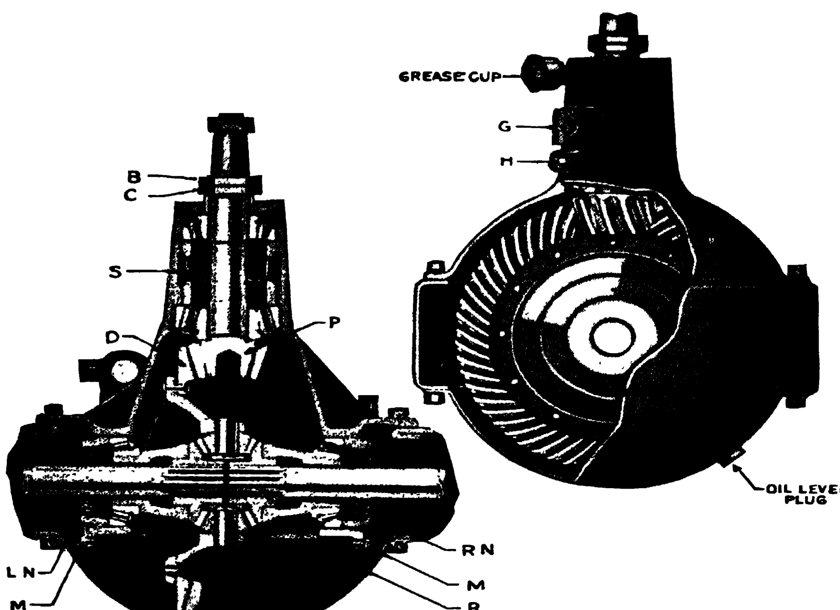


FIG. 25.—Differential Gear Set.

ferential gear on the end of the axle shaft revolves the four differential pinions. The teeth on the opposite side naturally travel in the opposite direction, thus turning the right differential gear backward. This is the identical action which takes place when one wheel is turning faster than the other while the car is in motion, except that at the same time there is a forward motion of the whole mechanism.

Ring Gear and Pinion.—The ring gear and pinion require much more attention and repair than do the differential gears. Within recent years the teeth have been changed from a straight to a helical type. Figure 15 shows the bevel ring gear and driving pinion in a Buick car. In this type the propeller shaft transmits the power from the universal joint to the driving gears of the differential. For its entire length it is enclosed in a steel tube carrying the driving flange which attaches to the universal joint housing on the rear of the transmission.

The driving effort from the rear wheels is transmitted by the pinion tube through the transmission case to the frame of the car. The pinion tube also absorbs the torque reaction of the bevel driving gears. At its rear end the propeller shaft is mounted on ball bearings and carries the driving pinion which meshes with the large ring gear on the differential.

The depth to which the pinion meshes with the teeth of the ring gear is adjustable and adjustment can be made by removing the cover plate on the right side of the pinion flange and loosening the adjusting sleeve clamp screw. The sleeve which carries the outer bearing can then be turned to adjust the position of the pinion.

The adjustment of the pinion and bevel gear must be carefully made in order that the correct contact of the teeth may be secured. Most of the noises in the differential housing are due to poor adjustment of these gears.

In mounting the ring gear on the differential, inspect the ring gear seat of the differential case to determine whether it runs true with the bearing hubs. If it runs out more than 0.002 inch, face it off in a lathe to make it true. When riveting the ring gear on the case, make certain that it is riveted tight. Ring gears should not run out more than 0.005 inch, using the bearing hubs of the differentials as centers.

When driving the pinion on the shaft be sure that it does not ride the key and that it is driven on tight. The pinion should not run out more than 0.002 inch on the shaft.

The common method of setting up *spiral bevel gears* is to set the ring gear and pinion so they come together flush, either at the large or small end of the teeth, and have an operating clearance of from 0.006 inch to 0.008 inch. An experienced mechanic can very often locate the proper running position by his sense of touch, but this, too, is not always

dependable since correct adjustment depends largely on the cut of the gear and the variation that takes place in its manufacture.

The best way to place the gears back into the axle is to roll the pinion around the ring gear by hand and note the position which the pinion takes at the large or small end—whether it sticks out or runs in. Assemble them in the axle as nearly as possible in that position, allowing from 0.006 to 0.008 inch backlash between them. Place the axle under

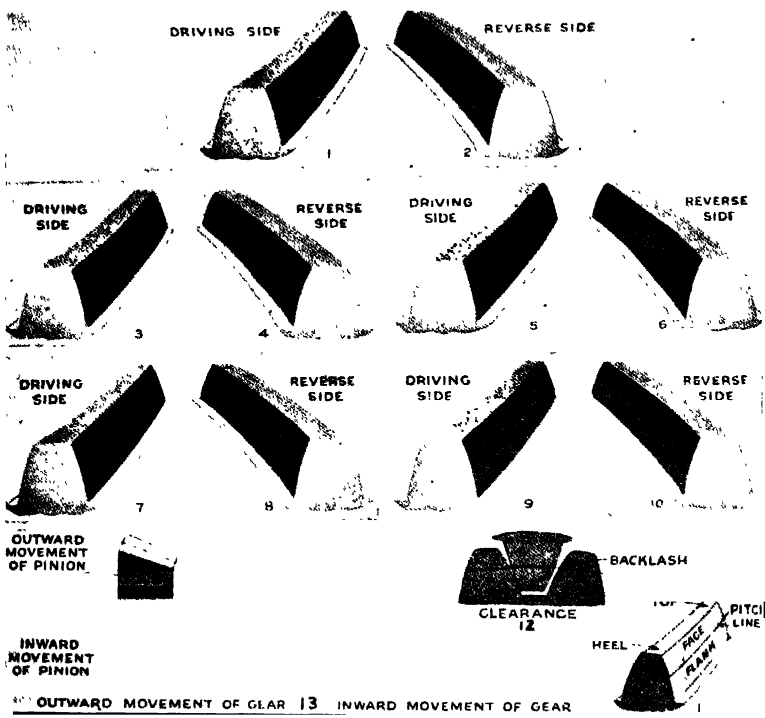


FIG. 26.—Adjustment of Bevel Gears in Assembly.

the car and paint the gear teeth with a thin coat of white lead. After this is done jack up the rear wheels and start the motor, throwing the transmission into high gear. Also throw in the brake, which must be equalized, with about the same load on each wheel. This will wipe the paint off the teeth. The condition illustrated in (9) and (10) Fig. 26, may be found to exist. The shaded portion represents the contact of the gear, which means the load is pulling on this portion of the teeth. In this case, move the pinion in, or toward the rear, two, three, or more notches of the adjusting nut, until the pinion wipes off the paint as shown

in the shading on (1) and (2). This position illustrates a desirable contact on the spiral tooth of the ring gear. The contact as shown is just a trifle heavier on the toe of the tooth (11) than it is on the heel. The heel of the gear tooth is the large end, and the toe is the small end. The gears are set this way to make sure that an even contact is obtained when a full load is applied, the pinion in that case always having a tendency to lift.

If there is a contact such as that illustrated in (7) and (8) or where the load comes on what is called the flank of the gear tooth, it means that the pinion is too far in toward the axle. Gears set up in this way are noisy. To correct, pull the pinion out until contact comes to the full working depth of the gear tooth, without leaving the lowest point of con-contact (see (1) and (2)). If the contact is as shown in (7) and (8) and (9) and (10) it should be changed only by moving the pinion. If the load is centered in these places a noisy axle will be the result. Noise can be eliminated almost always by the pinion adjustment.

If the contact on the tooth appears as shown by the shading in (3) and (4) it means that there is too much backlash between the ring gear and pinion. Gears set up this way will eventually break off at the heel, the large end of the gear (11). To correct, move the ring gear toward the pinion, but be sure there is some backlash as gears cannot be run too tight. If the contact still shows heavy on the heel, change the gears. If this does not relieve the contact, the axle is machined wrong or is sprung.

Contact that is heavy on the small end or the toe of the tooth is not bad, although it should not be centered there too much (5) and (6). Gears set up in this way will eventually break off at the toe. To correct, move the ring gear away from the pinion.

Spiral bevel gears really are cones. (12) and (13) illustrate the difference obtained in backlash by moving either the ring gear or the pinion. For example, on a 4 : 1 gear ratio, it would be necessary to move the pinion four times as much as the ring gear in order to get the same amount of backlash. For this reason, when it is necessary to increase or decrease the backlash, the ring gear should be moved.

Bearings.—To the unaided eye a highly polished bearing surface appears to present an unbroken and perfectly smooth surface. When subjected to examination under a powerful microscope the surface shows more or less uneven and broken pieces of metal which go to make up the whole part. Most machines depend upon bearings for the connection between different units and parts.

In all there are only six simple machines: the pulley, the wheel and axle, the screw, the inclined plane, the lever, and the wedge. The auto-

mobile is made up of many combinations of some or all of these simple machines. A machine may be used to gain a mechanical advantage such as is gained through a block and tackle or a jack screw, but its use

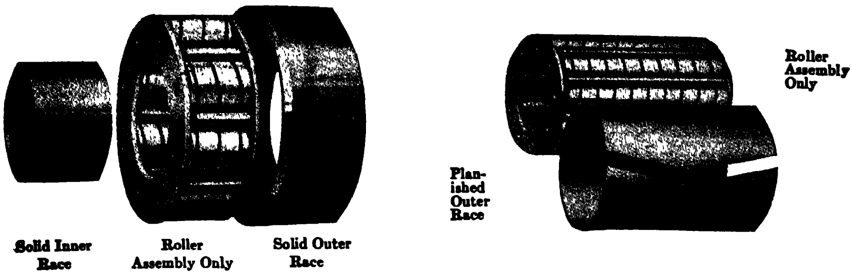


FIG. 27.—Hyatt Roller Bearings.

always occasions a loss in power due to the friction of moving parts. In actual practice a reduction has to be made from the advantage apparently gained because of the resistance of the machine to free motion.

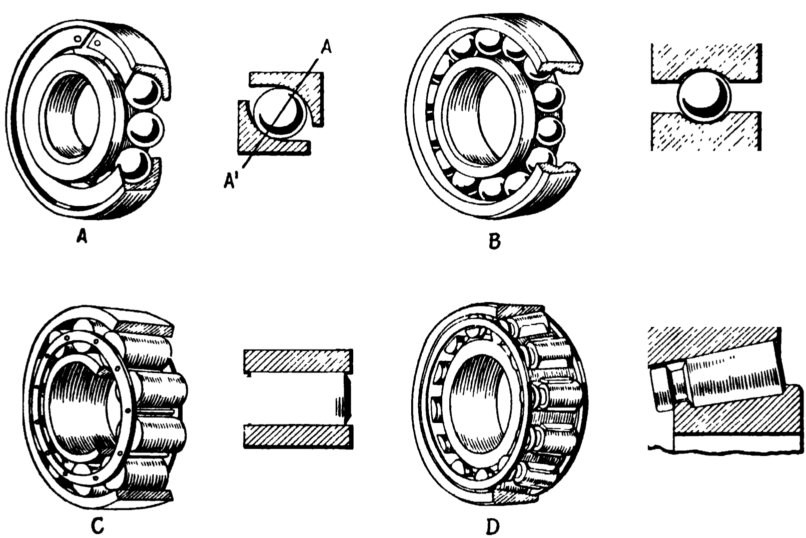


FIG. 28.—Types of Construction of Ball and Roller Bearings.

This resistance is due largely to the rough surfaces of the bearings between the moving parts of the machine.

To reduce the amount of friction the surfaces were first polished as smooth as possible and then a suitable lubricant was used to fill the rough surfaces, as is done in ordinary plain bearings. Later it was

found that the rolling friction of two surfaces was much than the sliding friction; therefore ball and roller bearings were developed.

Because of the difficulty in keeping a proper lubricant in plain bearings under all conditions, **anti-friction** bearings have been devised for use in the wheels, transmissions, differential, and other parts. These bearings may be classified into two main types, **ball** and **roller.** The **cup-and-cone** ball bearing, as illustrated in Fig. 28 *A*, is designed for both end thrust and radial load. (End thrust is parallel to the center line of the bearing and the radial load is perpendicular. See Fig. 29.) The annular ball bearing is designed for the radial load only, and is shown in Fig. 28 *B*. The annular roller bearing, as shown in Fig. 28 *C*, is made for a heavy radial load without end thrust, while the tapered roller bearing in Fig. 28 *D* will withstand a heavy radial load as well as an end thrust.

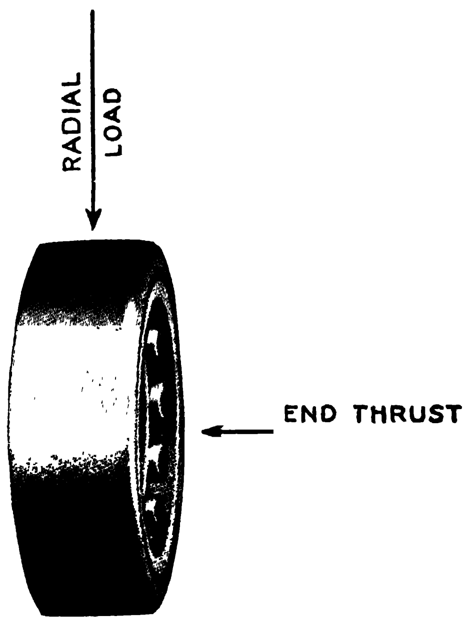


Fig. 29.—Direction of Stress on a Bearing.

Where it is desirable to use a plain bearing it is advantageous to make the bearing of bronze or babbitt metal and to use steel for the journals. This practice is followed largely in the case of connecting rod and crank-shaft bearings. The bearings should be kept in correct adjustment. Practically all bearings on the car are adjustable, and constant attention should be given to this very important phase of automobile work.

Good lubrication is essential to the efficiency of any bearing. The best lubricant should always be used since it is cheaper than new parts. Figure 32 illustrates the use of ball bearings for both radial and compression support. Throughout the moving parts of the automobile are located ball or roller bearings. They require little attention except to keep them correctly adjusted and well lubricated.

Brakes.—As a rule, both service and parking brakes are located on the rear wheels. The Model T Ford car has the foot brake as a part of the unit power plant, but most manufacturers prefer the former location. On

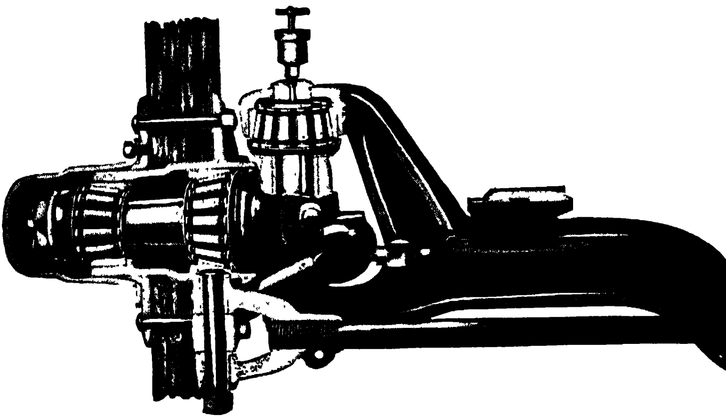


Fig. 30.—Timken Roller Bearings.

each wheel hub is attached a brake drum, around which the brake band is placed. On the rear wheel, in some cases, the parking brake is inside the drum; therefore it is called an internal brake. Many emergency brakes are located on the drive shaft near the transmission. The friction

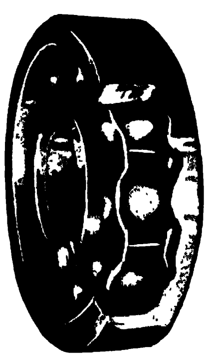


Fig. 31.—Ball Bearings.

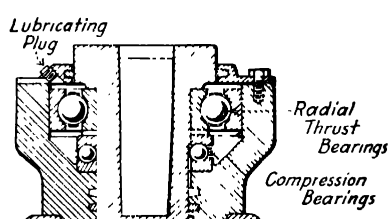


Fig. 32.—Ball Bearings Used for Compression and Radial Thrust.

caused by the contact of the band surface on the drum serves to brake the car; hence it is evident that friction is desired and lubrication is not needed. Brake-band linings of various kinds have been developed for contact with the metal of the brake drum. The large amount of heat

developed by frequent use of the brakes makes necessary a fabric which will not burn. For this reason asbestos is one of the principal materials used in the manufacture of brake bands.

Careful drivers do not depend entirely on the brakes for holding back the speed of the car when going down grade; they use the compression of the engine instead. This practice is necessary in descending long hills or in mountain driving.

A number of different methods for operating brakes have been introduced in recent years. Among these the following are in general use: the mechanical brake, the hydraulic brake, the air brake, the vacuum booster brake and the hydrostatic brake. The new four-wheel system is far superior to the old two-wheel brake mechanism. Each wheel takes its share of the load and the car is stopped very easily.

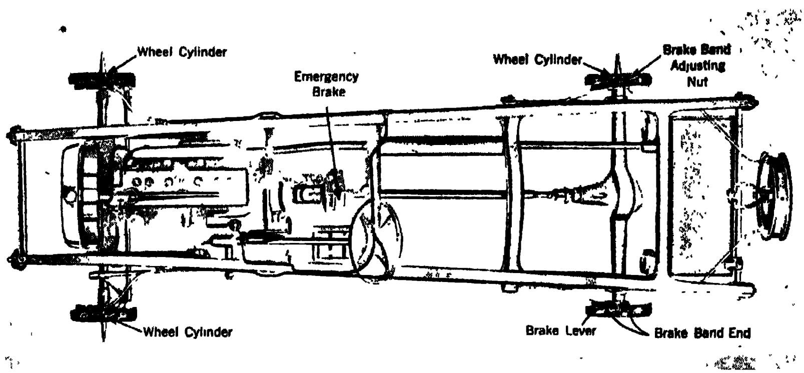


FIG. 33.—Hydraulic-brake Assembly.

The Hydraulic Brake. The hydraulic type of brake, shown in Fig. 33, is very popular. It is smooth in operation. The brake pedal when operated creates pressure in a cylinder, called the " master " cylinder, which is connected by tubing to each of the four wheel-brake mechanisms. Each wheel is equipped with a cylinder and two pistons, each piston being connected to an end of the brake band. When pressure is applied by the foot, the two pistons are forced apart, causing the band to tighten on the brake drum. The solution used in this system is a mixture of 50 per cent alcohol and 50 per cent chemically pure castor oil. Loose motion in the brake pedal indicates that the system needs more solution. In this case the repairman should refer to the manufacturer's manual for specific instructions.

The Mechanically Operated Brake.—The mechanically operated brake is used on some makes of cars. There are two types, the external

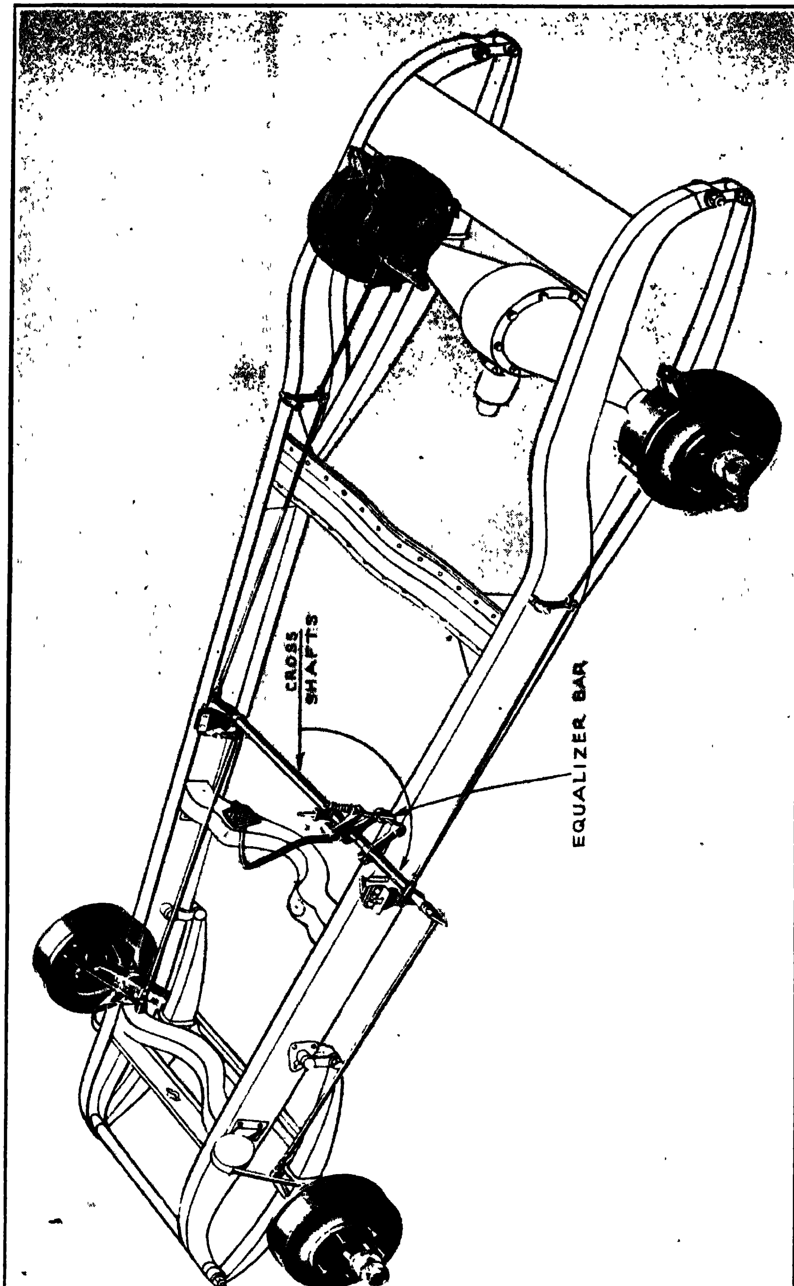


FIG. 34.—Mechanically Operated Brake. (Nash.)

and the internal. The brakes are operated by pull rods and cables. Points for adjustments are illustrated in Fig. 34. Adjustments can be made on the brake bands and rods. It is essential to keep all parts of this type of brake mechanism well lubricated.

The Vacuum Booster Brake.—Another type of brake is called the vacuum booster brake. It is operated by a plunger in a cylinder in which a vacuum is created by being connected with the intake manifold. It is of a mechanical design only in that the pressure of applying the brakes is exerted by a piston operated by the vacuum taken from the intake manifold. This type of brake is illustrated in Fig. 35.

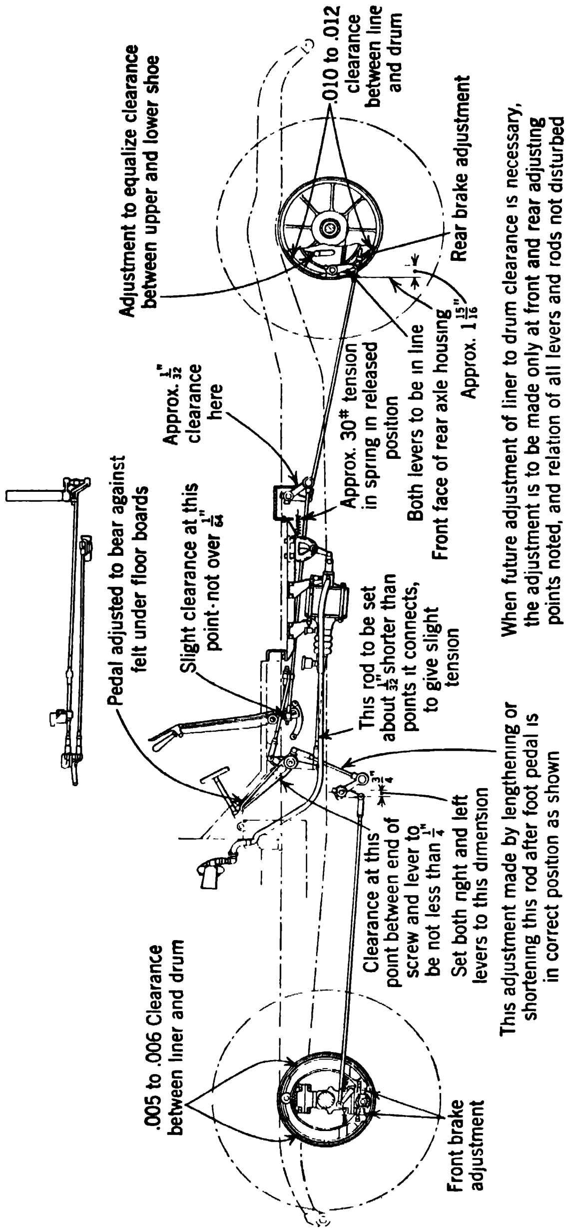


FIG. 35.—Vacuum Booster Brake. (Pierce-Arrow.)

The Air Brake.—The air brake as shown in Fig. 36, is used on buses and large trucks. The action is similar to that

of the hydraulic brake, except that the force is transmitted by air instead of by a liquid.

The Hydrostatic Brake.—There is another brake called the hydrostatic brake. This is illustrated in Fig. 37. All brake rods and mechanical joints are eliminated in the hydrostatic brake. The pressure is created by a sealed elastic sack which is compressed by a diaphragm

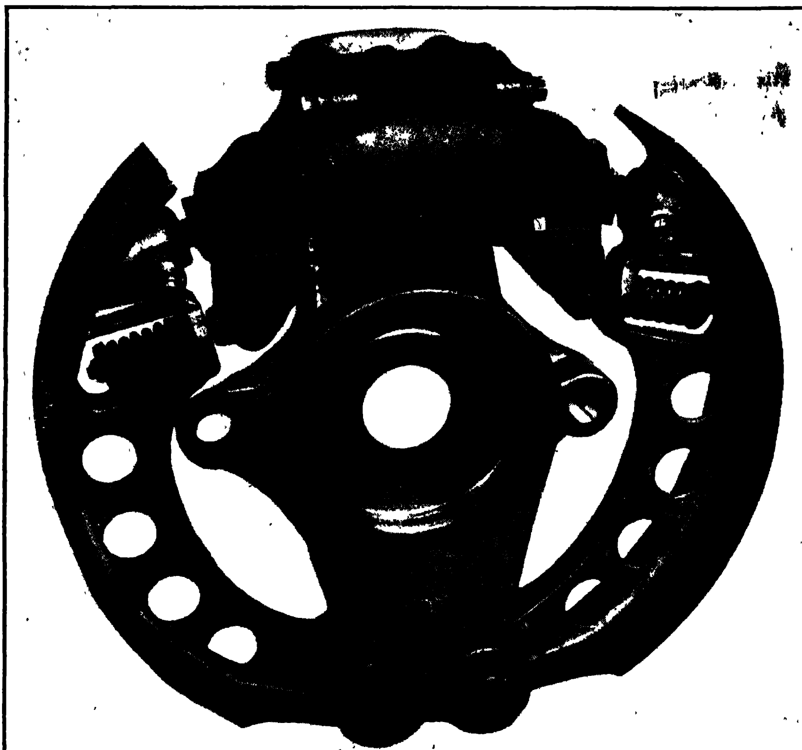


Fig. 36.—Cylinder type Brake-Mechanism. (Buda.)

action caused by the brake pedal. Each brake is connected by a tube, one end attached to the braking mechanism of the wheel and the other to the sealed sack. The pressure caused by compressing this elastic sack by the movement of the brake pedal causes the tubes inside of the brake drum Fig. 38 to expand, forcing the brake shoes against the drums. The braking energy is applied equally all around the drum and on all four wheels.

Full instructions for relining and adjusting brakes are given in Job No. 19 on Chassis Work. The life of the brake linings depends almost

entirely on the operator. He can burn out newly lined brakes in a very short time, or by careful use he may drive many thousands of miles before a change of lining is necessary. In stopping the car or slowing up, always apply the brakes gradually. To slow up the car speed, reduce

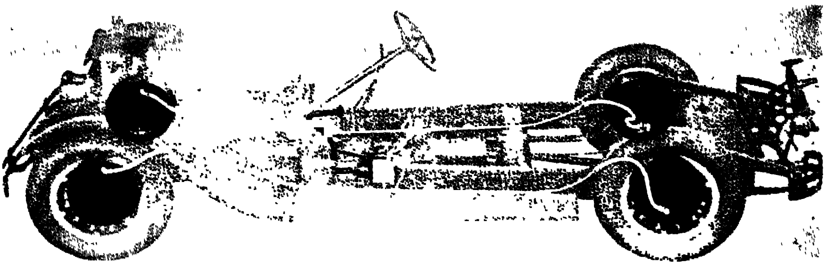


Fig. 37.—The Hydrostatic Brake. (Stutz.)

the engine speed as much as possible by closing the throttle, disengaging the clutch, and applying the brakes. Do not apply the brakes suddenly upon a swiftly moving car unless it is absolutely necessary. When descending very steep hills the brakes can be assisted by shifting the gears into low speed, engaging the clutch, closing the throttle, and allowing the engine to be turned over against compression by the coasting of the car.

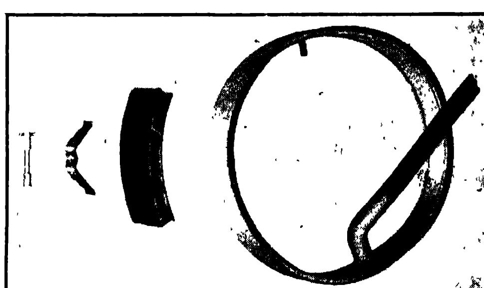


Fig. 38.—Hydrostatic Brake Tube.

Clutches.—A gasoline engine cannot be started under load except with great difficulty, and for this reason the engine is connected to the driving mechanism by means of a friction clutch which can be released by pressing down on the clutch pedal and applied so as to take up the torque gradually. On modern cars the clutch is located just back of the flywheel and in front of the transmission. Clutches may be divided into three main types:

1. Cone Clutches (Fig. 39).
2. Multiple-disk Clutches using
   a. Dry Plates (Fig. 41). *b.* Plates in Oil (Fig. 42).
3. Single-plate Clutch (Fig. 40).

The clutch is a device which serves to connect or disconnect the engine from the transmission and therefore from the rear wheels. It provides the means whereby the driver may stop the car without stopping his engine. The clutch is operated by means of the left-hand foot pedal which projects through the toe boards. The clutch is normally engaged so that the power is transmitted from the engine to the rear wheels without any effort being exerted by the driver. To disconnect

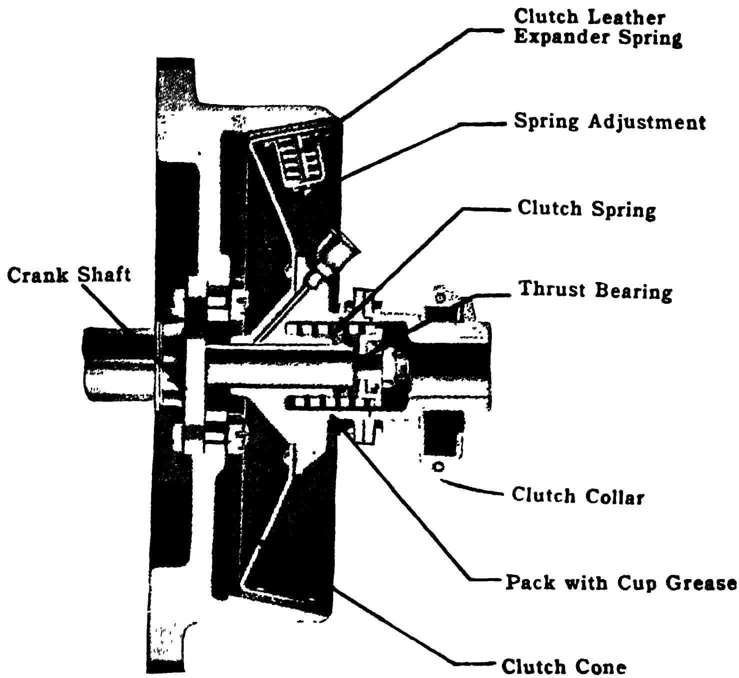


FIG. 39.—Cone Clutch.

the engine from the rear wheels the clutch must be disengaged or released. To do this the driver has merely to press down upon the clutch pedal. The clutch is normally held in engagement by a coiled spring. In addition to disconnecting the engine from the road wheels when the driver desires to stop the car, the clutch is also used to disconnect the engine from the transmission unit while the gears are being shifted.

The clutch shown in Fig. 39 is of the leather-faced cone type, with six compensating springs under the leather for easy engagement. High-

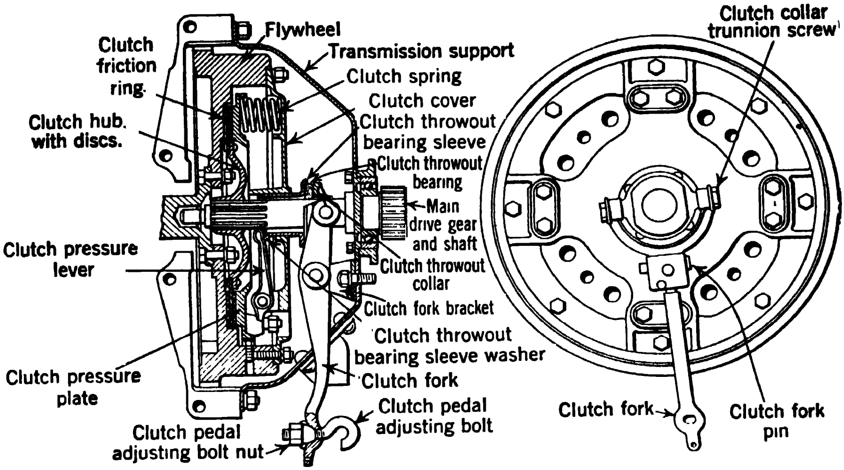


FIG. 40.—Single-disk Dry-plate Clutch. (Chevrolet.)

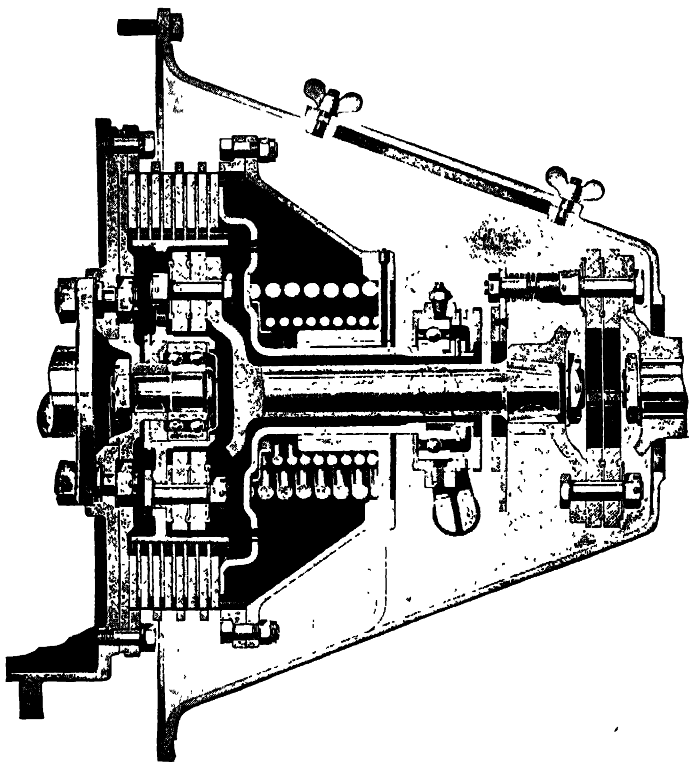


FIG. 41.—Multiple-disk Clutch—Dry Type.

grade, one-piece leather should be used for the facing and, if properly handled, should seldom need to be replaced.

The six compensating plunger springs hold the facing away from the cone at these points, and when the clutch is engaged these high points come into contact with the surface on the flywheel first, thus assuring a gradual application of the clutch. These springs prevent "grabbing."

Figure 41 shows a multiple-disk dry-plate clutch. In this type the driving and driven disks are stampings carefully flattened and machined to make them slide freely.

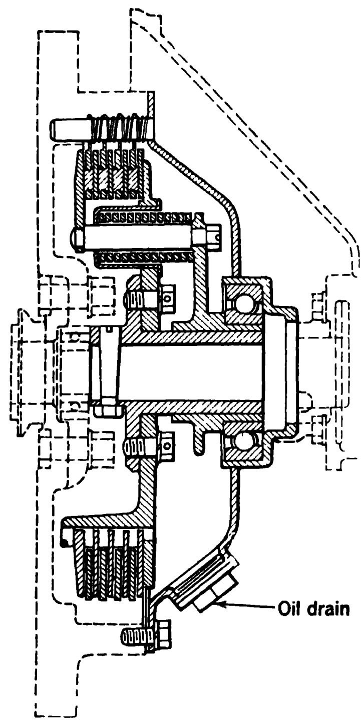


FIG. 42.—Multiple-disk Clutch Running in Oil.

The thrust of throwing out the clutch is taken on an anti-friction bearing, which fits into a recess in the face of the sleeve. It is important that this bearing be sufficiently lubricated at all times.

The need for clutch adjustment is simple to determine. Whenever the transmission gears do not stop, the adjustment needs attention.

The multiple-disk clutch running in oil (Fig. 42) is inclosed in an oil-filled case. In most cases the disks are made of steel. A few multiple-disk clutches have been constructed with cork inserts. A slipping clutch of this type is caused in most cases by a weak clutch spring. If it grabs, the clutch spring will be found to be too tight or the oil too thin.

The Chrysler clutch (Fig. 25c), Chapter I, is of the dry-plate type. The flywheel face serves as the driving disk, and the driven disk is coupled to the transmission by the clutch shaft. The driven disk is faced on both sides with a friction material composed largely of asbestos, which makes contact with the lever plate on one side and the flywheel on the other. The pressure is applied through levers on the lever plate by the tension of coil springs. Pressure upon the left foot pedal turns the pedal shaft. This action, by means of the clutch fingers, slides the

shifter sleeve back on the clutch shaft and causes the coil springs to contract and relieve the pressure on the disk, causing the clutch to disengage.

After the car has been driven for some time, it may be found that the facings on the clutch disk have become compressed or worn, causing the clutch to slip.

The clutch shown in Fig. 43 is the well-known Borg & Beck type dry-plate clutch. Some pilot bearings, or the ones in the flywheel on which the clutch shaft floats are known as "oilless bearings." These are

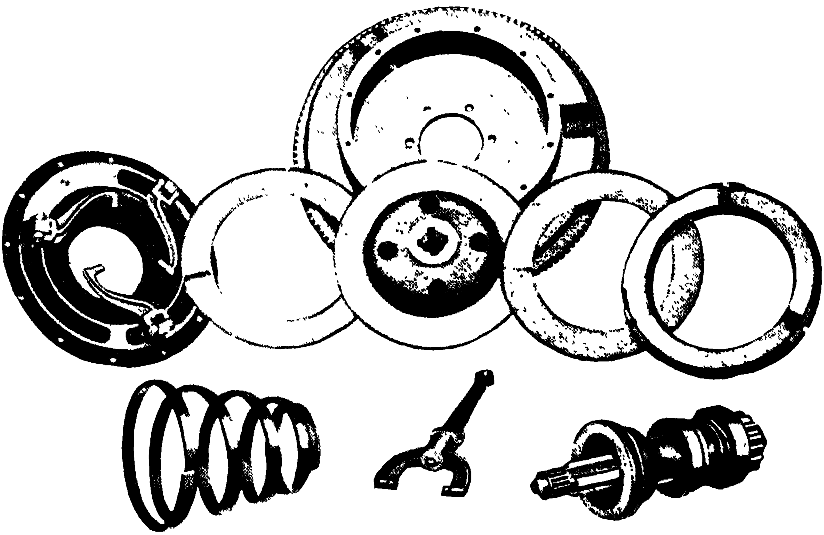


FIG. 43.—Clutch Dry-plate Type. (Borg & Beck.)

bronze bearings with oil grooves in which is placed compressed graphite which acts as a lubricant. For adjustment see Job No. 25, Chapter I.

Transmissions.—The gasoline engine differs from the steam or electric power producers in that it cannot continue to give a strong pull at the very lowest engine speeds without a multiplication of cylinders. Hence, under conditions where low car speeds are necessary, there must be some means of increasing the relative speed of the engine. This is accomplished by a set of gears. The reverse gear is conveniently incorporated in the same train of gears.

The main drive gear (*E*, Fig. 45) is flanged to a shaft which turns with the motor when the clutch is engaged. This gear is always in mesh with the larger gear (Fig. 46, *F*) on the countershaft below. The countershaft extends rearward and carries three other gears of varying

size. Above the countershaft is a squared shaft continuing the direction of the main-drive gear shaft, but free to move independently of it. This squared shaft carries two gears *H* and *J*, Fig. 47, with squared holes, which must turn with the shaft, but which may slide forward and back upon it. The large sliding gear *H* is for low and reverse speeds and the smaller gear *J* is for intermediate and high. *Neutral* (Fig. 45) is the shifting lever position when both these gears are riding free in the space between their respective engaged positions.

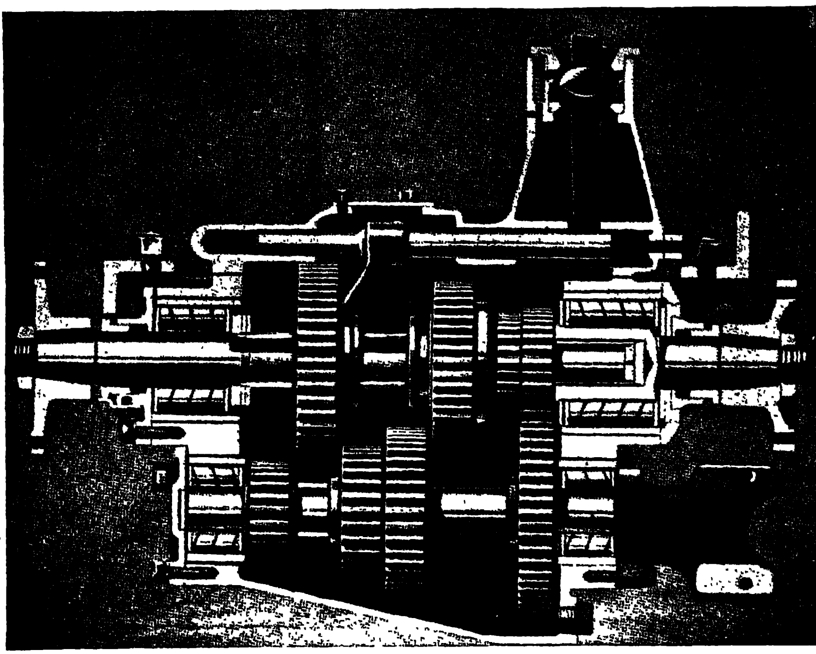


Fig. 44.—Sectional View of Sliding Gear Transmission.

When the operator throws the lever into low-speed position (Fig. 46) a finger forces the larger gear *H* to slide into mesh with a small gear *G* on the countershaft. The square drive shaft then revolves much more slowly than the engine, giving greater power and correspondingly less speed to the rear wheels. Intermediate speed position causes the gear *I* (Fig. 47) to mesh with a larger countershaft gear *J*, giving more speed. For high speed this gear *J* slides forward, engaging a clutch on the main drive gear *E* (Fig. 48) directly, thus making the drive shafts virtually into one continuous shaft. For reverse, the large

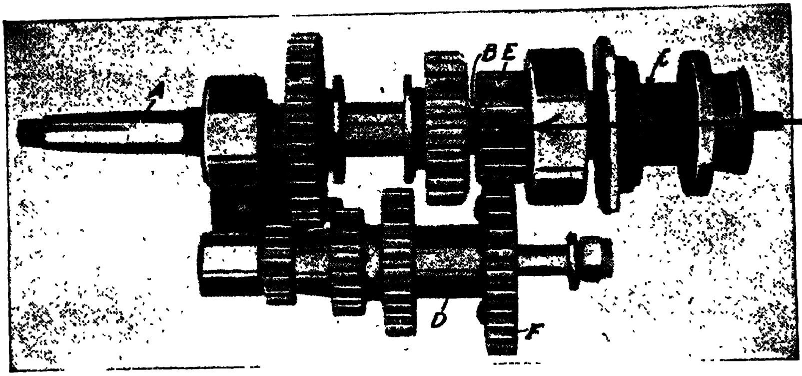


FIG. 45.—Neutral-gear Position.

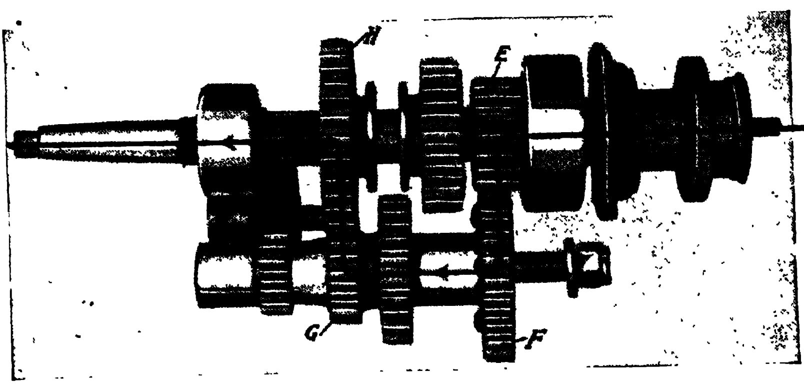


FIG. 46.—Low-gear Position.

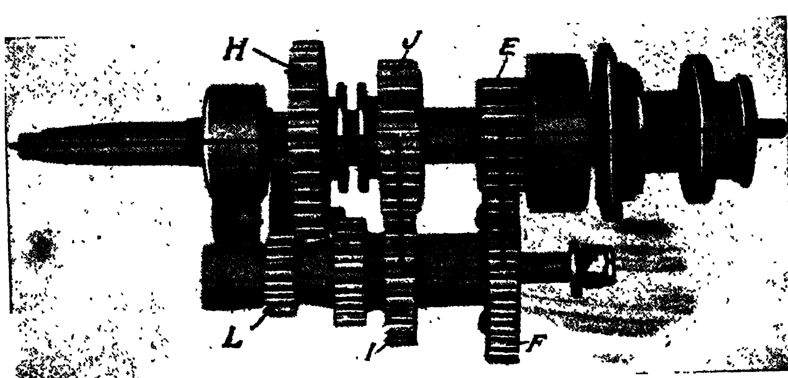


FIG. 47.—Intermediate-gear Position.

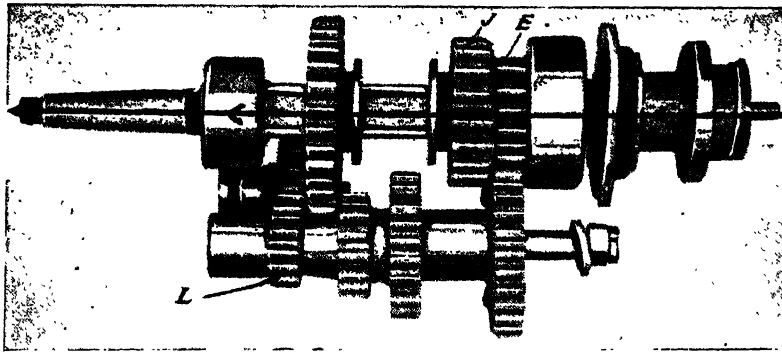


FIG. 48.—High-gear Position.

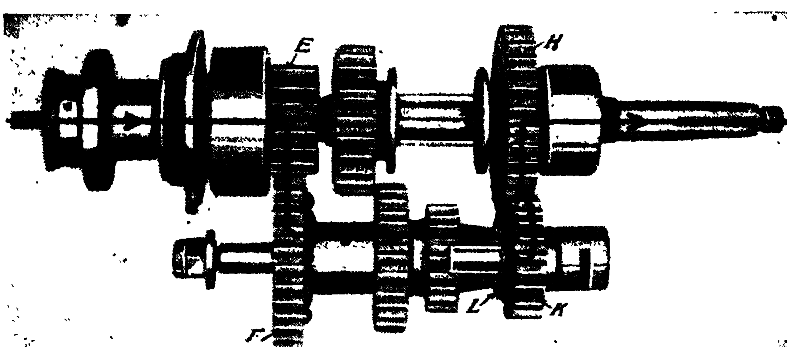


FIG. 49.—Reverse-gear Position.

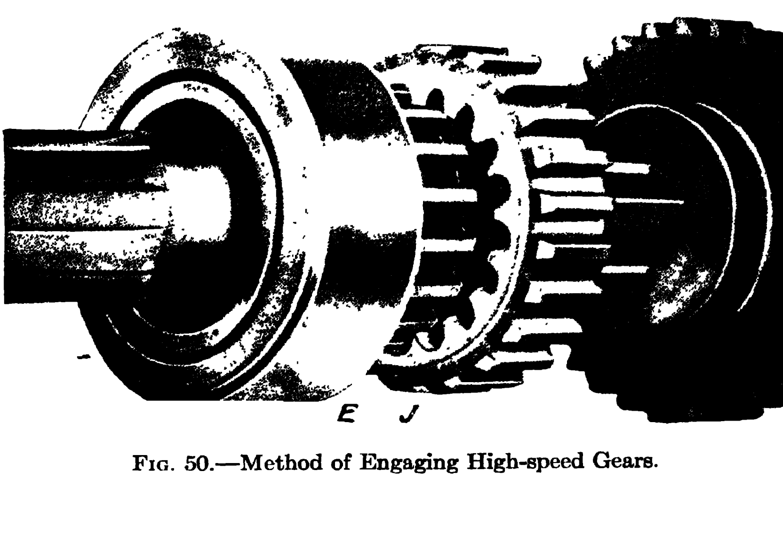


FIG. 50.—Method of Engaging High-speed Gears.

sliding gear H (Fig. 49) is made to engage a small idler gear K which meshes with the countershaft gear L instead of directly on the countershaft gear, thus changing its direction of rotation.

It will be seen that the whole drive system from engine to wheels, from a control standpoint, is in three independent sections, with the two joints between them at the clutch and gear case, respectively. The center section must be free to move with the rear whenever the rear connection is changed, as in shifting gears; hence the necessity of throwing out the clutch whenever the gears are changed. Letting

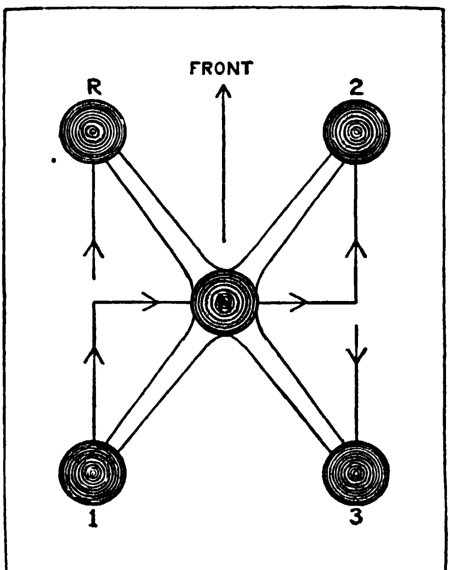


FIG. 51.—Typical Gear-shifting Diagram.

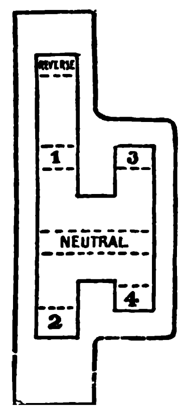


FIG. 52.—Change Gear Positions on a Four-forward Speed Transmission.

in the clutch with the lever *in gear* connects the remaining link and permits the motive power to be applied to the rear wheels. A thorough understanding of this point will make every characteristic control operation perfectly clear. For instance, it will explain why it is necessary to wait for the center section to slow down slightly in shifting *up* and why speeding up the engine with clutch re-engaged when the gear lever is coming through neutral makes a perfect shift when *stepping down*.

Figures 53 to 57 illustrate the gears in a four-forward speed transmission. The mechanism operates in a manner similar to that described for a three-speed gear set. When in high or fourth speed the drive is not direct but the ratio is raised as shown in Fig. 56. This reduces the rela-

tive power but increases the speed of the car with the engine. In the third speed (Fig. 55) the drive becomes direct. A little study of the

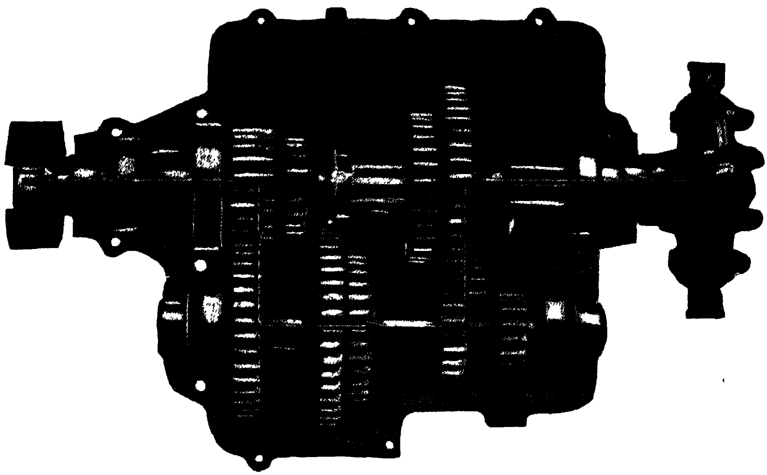


Fig. 53.—Transmission Gears in First or Low Speed. (Four-speed Transmission.)

figures following the arrows indicating the path of the propelling force will make clear the action of this transmission.

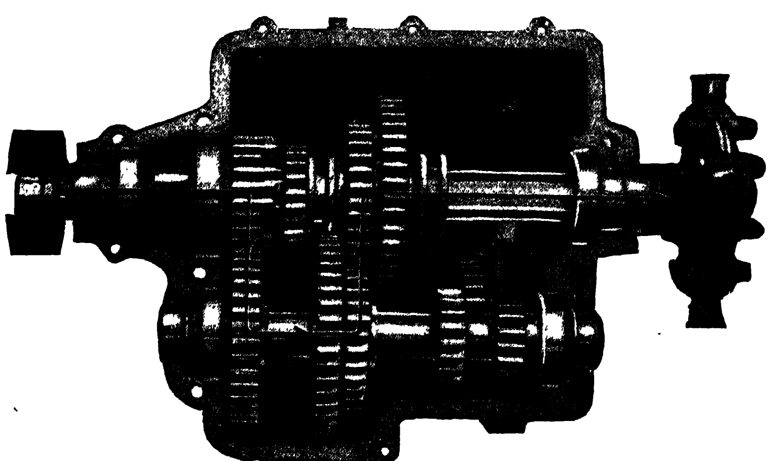


Fig. 54.—Transmission Gears in Second Speed. (Four-speed Transmission.)

Wheels.—The kind of construction and the kind of material which enter into the wheels of an automobile are very important. Under

average road conditions the wheels are subjected to sudden strains which, if the wheels fail to stand up under the extra stresses, may cause

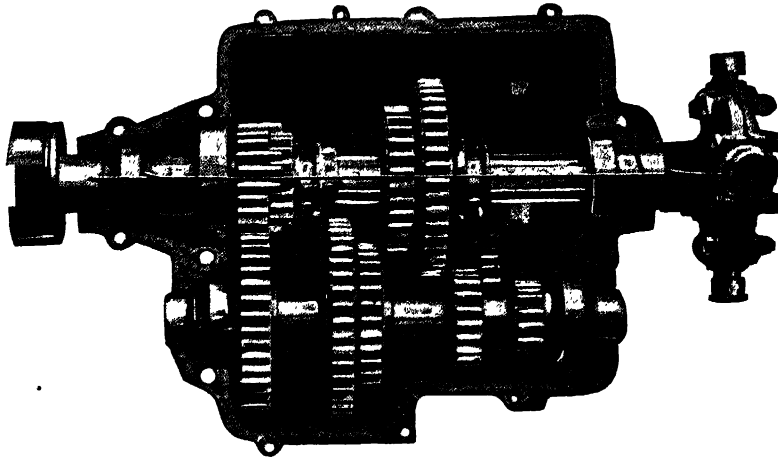


Fig. 55.—Transmission Gears in Direct or Third Speed. (Four-speed Transmission.)

serious injury to the passengers. In addition to the need for strength, poorly constructed wheels are frequent sources of annoyance on account of squeaks.

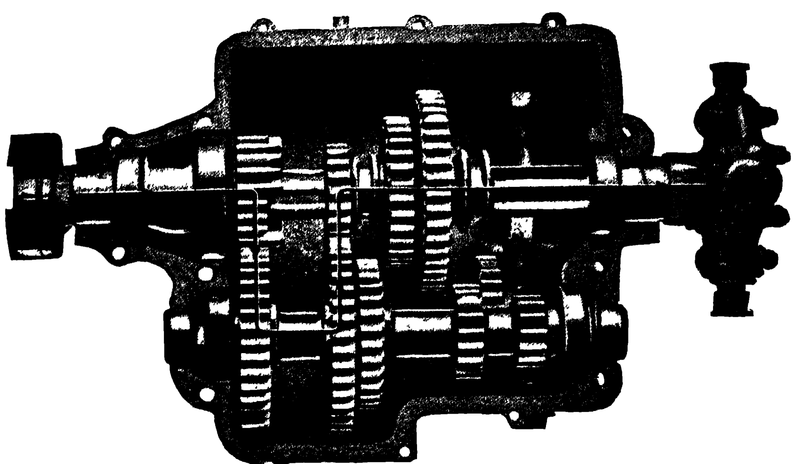


Fig. 56.—Transmission Gears in Fourth or High Speed. (Four-speed Transmission.)

Three common types of wheels are in use on passenger cars: The wooden artillery wheel (Fig. 58); the wire wheel (Fig. 59); and the disk wheel (Fig. 60).

The wheels are a good part of the unsprung load on the automobile and as such are subjected to severe jolting over rough roads. To be efficient they should be light and strong. The felloe is made of wood

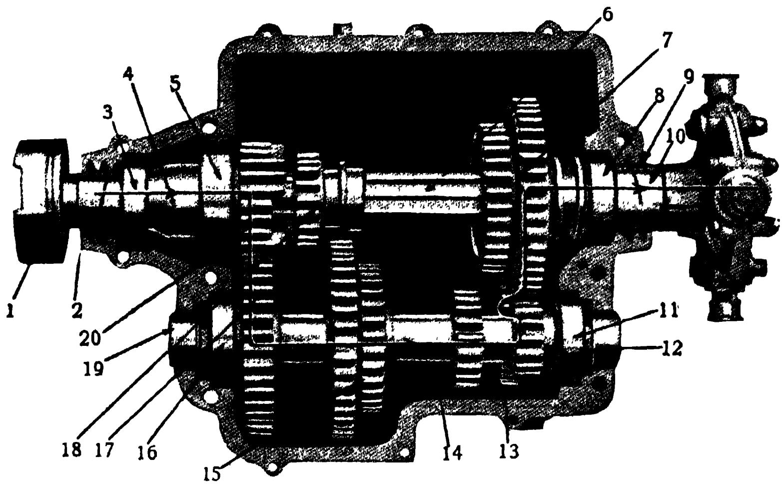


FIG. 57.—Transmission Gears in Reverse Speed. (Four-speed Transmission.)

except on wire wheels. All types use a metal rim to support the tire. Some wheels use a removable rim while others retain the permanent rim. The removable rim is a great convenience in tire trouble since it permits the carrying of an inflated tire all ready for mounting.

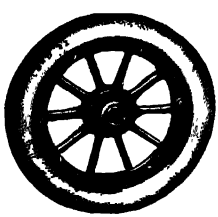


FIG. 58.—Artillery-type Wooden Wheel.

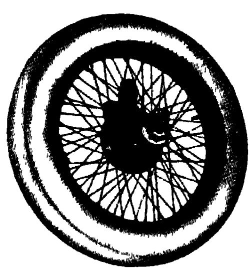


FIG. 59.—Wire Wheel.

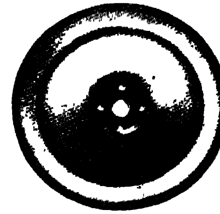


FIG. 60.—Disteel or Pressed Steel Wheel.

The tendency at the present time is toward a wider use of the wire wheel on passenger cars. As a rule, wire wheels do not use demountable rims, a fifth wheel being carried.

Disk wheels are easier to clean than either the artillery or the wire wheels and cause less friction in muddy ruts.

The scarcity of well-seasoned hickory for wooden spokes will probably cause more manufacturers to use metal wheels, either of the wire or of the pressed-steel disk types.

Wire wheels have a greater resiliency than either of the other types but are more apt to be injured in country driving where deep ruts are found.

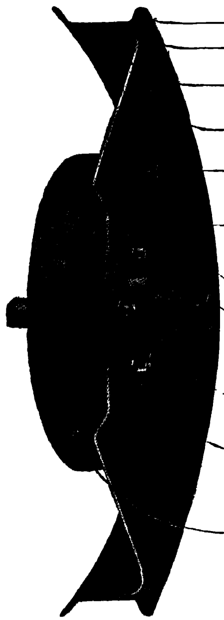


FIG. 61.—Section of Disteel Wheel.

Questions.

1. What are the different types of body springs?
2. How are springs lubricated?
3. What are the types of steering mechanisms in common use?
4. What are the requirements of a good steering gear?
5. What is the function of a clutch?
6. What types are used?
7. How are Borg & Beck clutches adjusted?
8. What attention should be given cone-clutch leathers?
9. How should the clutch be used?
10. Name the different parts of the steering mechanism.
11. What is the function of the transmission?
12. What is the difference in construction between a three- and four-forward speed transmission?

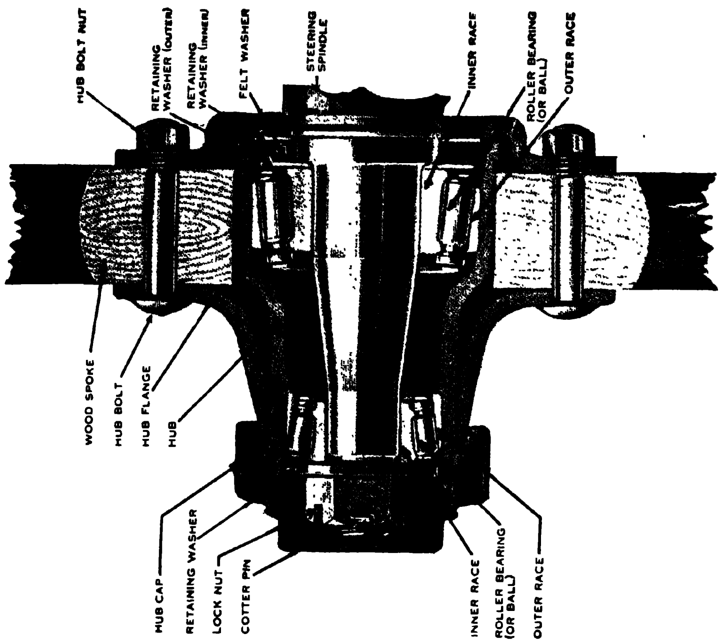


FIG. 63.—Sectional View of Wood-wheel Hub.

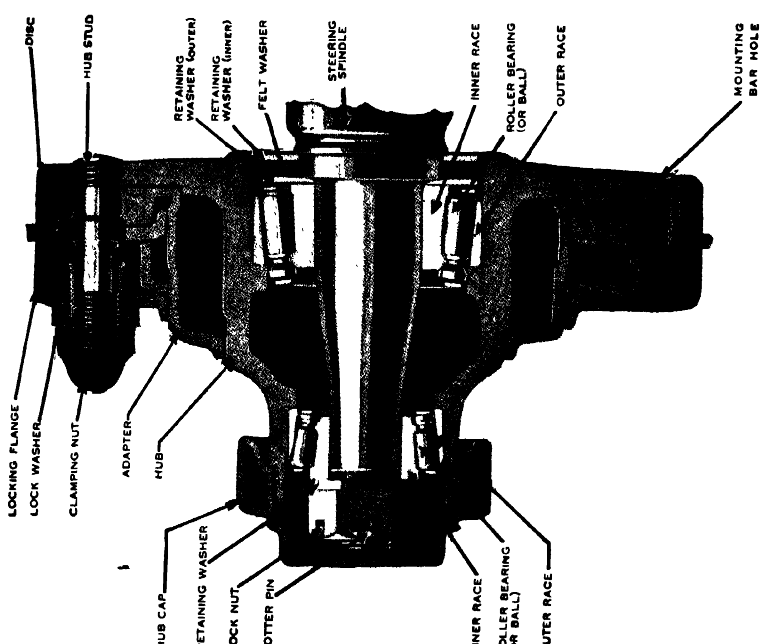


FIG. 62.—Section of Disteel Hub.

13. What controls the design of a front axle from a standpoint of easy steering?
14. What is the purpose of the differential?
15. What types are commonly used?
16. How is it lubricated?
17. How are differentials removed?
18. What are universal joints?
19. What types of rear axles are used?
20. What are the essential differences in each type?

CHAPTER VIII

AUTOMOTIVE ENGINES

GAS ENGINES have been in use for more than two hundred years. The evolution of the gas engine from the primitive, crude, one-cylinder apparatus of 1880 to the complicated but efficient modern multiple cylinder-engine of to-day is a story of wonderful mechanical ingenuity and achievement. The production of gasoline made possible the application of the gas engine to the automobile as well as to a great variety of other practical uses.

Throughout the long period of development the principles upon which the gas engine operates have remained the same—an *explosive fuel, compression,* and *ignition.* Many kinds of fuels have been used, such as gunpowder, artificial gas, natural gas, turpentine, benzine, alcohol, and crude oil and its by-products. Any combustible substance that can be mixed with air or oxygen to form an explosive may be used. Most automotive engines are now operated on various grades of gasoline, but the time is not far distant when a new fuel must be obtained. Research engineers are now at work seeking new and satisfactory fuels which can be obtained in sufficient quantities, at a reasonable cost, to take the place of our rapidly decreasing supply of petroleum, from which gasoline is distilled. Changes in fuels will require changes in the equipment necessary to prepare the fuel for use in engines. The "fuel mixers" of thirty years ago and the modern carburetor are good examples of such a development in equipment.

Compression has become standardized both in degree for efficient operation and in methods of compressing the mixture. Some types of stationary engines compress the fuel by pumps into tanks. Automotive engines, however, depend entirely upon the piston displacement to secure the compression needed.

Probably methods of *igniting the mixture* and ignition apparatus have undergone more changes in the process of improvement than have either fuels or engine design. Early engines used a flame which heated the end of the cylinder to vaporize the fuel, and after compression a flame was introduced through an open port to ignite the mixture. This method was superseded by the use of a hot platinum point heated

by a flame outside the cylinder, and this in turn gave way to our modern electrical spark.

Theory of Gas Engines.—The gas engine is a mechanical device for converting into a mechanical motion the energy stored up in certain fuels. Of itself, the engine has no latent power, but serves only to transform the latent fuel energy into usable mechanical energy. To make this transformation three things are necessary: (1) *A combustible fuel must be supplied*, (2) *the fuel or mixture must be compressed*, and (3) the *mixture must be ignited while under compression*. To provide these three conditions is the mechanical function of the gas engine.

As a mechanical means of introducing and compressing the fuel, Otto and Langen developed the modern 4-stroke-cycle engine, in which the successive strokes of the piston for two full revolutions of the flywheel were made to function as follows:

1. *Intake*, or drawing in the mixture by the downward stroke of the piston.
2. *Compression*, or compressing the mixture through the upward stroke of the piston.
3. *Power stroke*, the piston forced downward after ignition by the expanding gases.
4. *Exhaust stroke*, or the expelling of the expanded gases through the upward stroke of the piston.

In the above cycle an electrical spark is used to ignite the mixture at the moment of greatest compression. While Otto used the four cycles to draw in, compress, deliver the power, and discharge the waste gases, Clerk a few years later developed the 2-stroke-cycle engine, which delivered a power stroke for each revolution.

Theory of Gases.—All gases expand when heated. If a given volume of confined gas can be heated suddenly, it will exert a pressure on the walls of its container. When the explosive mixture of gasoline vapor and air is confined in the cylinder the heat liberated by burning the mixture increases the temperature of the gases and thereby increases the pressure of the gases on the walls of the cylinder and on the piston. The pressure of a confined gas is distributed equally at all points, and since in the case of the gas engine the piston is free to move it is forced downward on the power stroke.

An appreciation of the fact that the heat value of the fuel measures the quality of the gasoline, or other fuel, and determines its value to the consumer, will go a long way in helping one to understand the theory of gas engines.

The unit of heat known as the B.T.U. (British Thermal Unit), or the amount of heat required to raise the temperature of 1 pound of

water 1° F., is used in expressing the heat value of different fuels. (See Chapter XIII on Fuels.)

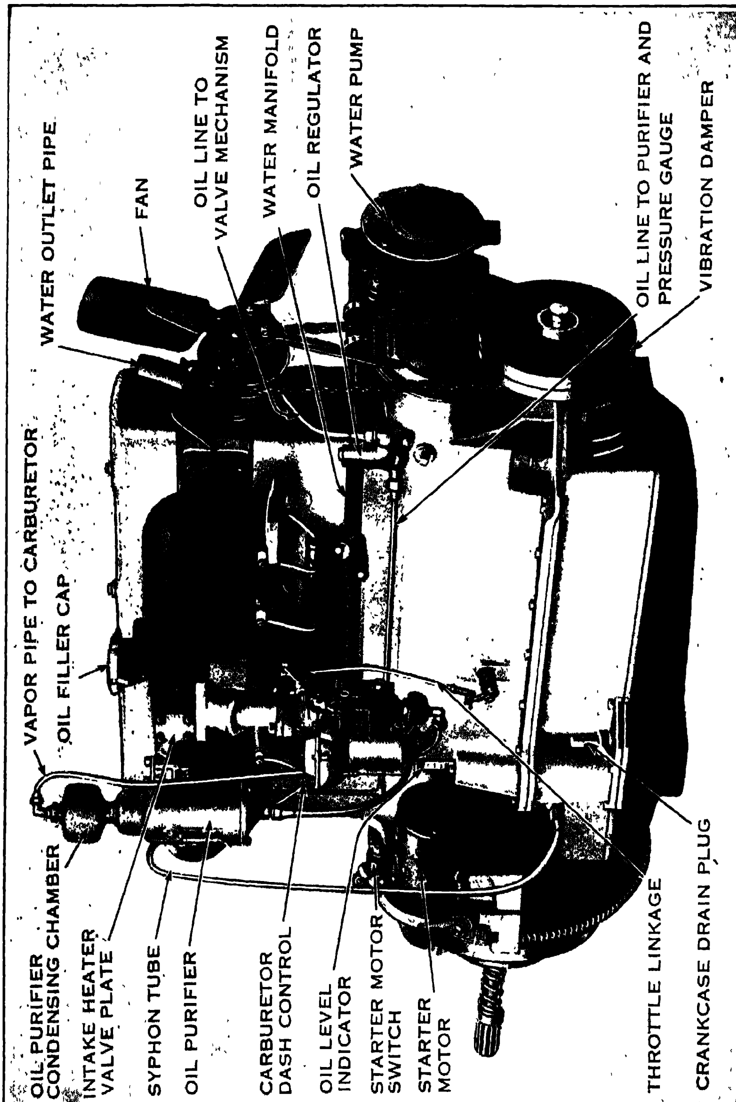


FIG. 64.—The Engine, Right Side. (Marmon.)

Figure 64 shows a side view of a modern six-cylinder unit power plant (Marmon) completely assembled. Figure 65 shows the front end view of a Chrysler engine. Figure 66 and 1a (Chapter II) illustrate interior views of a Buick Six and a Marmon Six.

The engine (Fig. 66) consists essentially of a row of six cylinders in which the gas is exploded, the force of the explosions acting on pistons which move up and down in the cylinders. The pistons are connected by means of the connecting rods to the crank shaft (see Fig. 4*a*, p. 107,

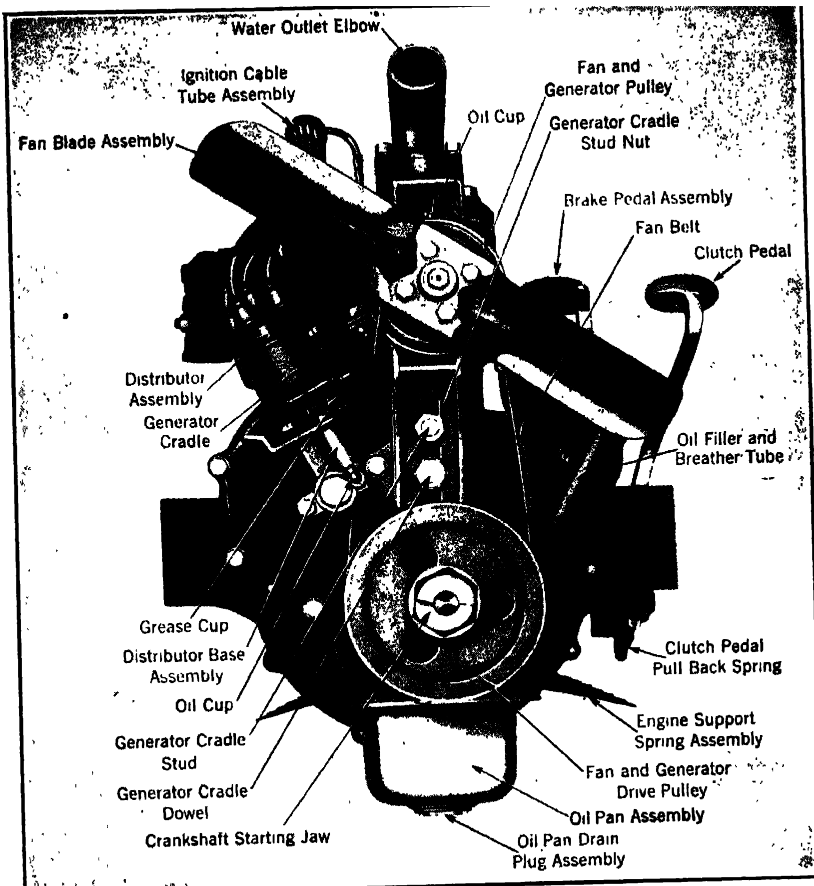


FIG. 65.—Engine, Front End. (Chrysler.)

Buick Valve Mechanism), and as they move up and down turn the crank shaft around in a clockwise direction. At its rear end the crank shaft carries a heavy flywheel which engages with the clutch and transmits the power to the rear wheels. Teeth are cut around the rim of the flywheel, and a small gear, driven by the electric starter, engages with these teeth when spinning the crank shaft to start the motor. The

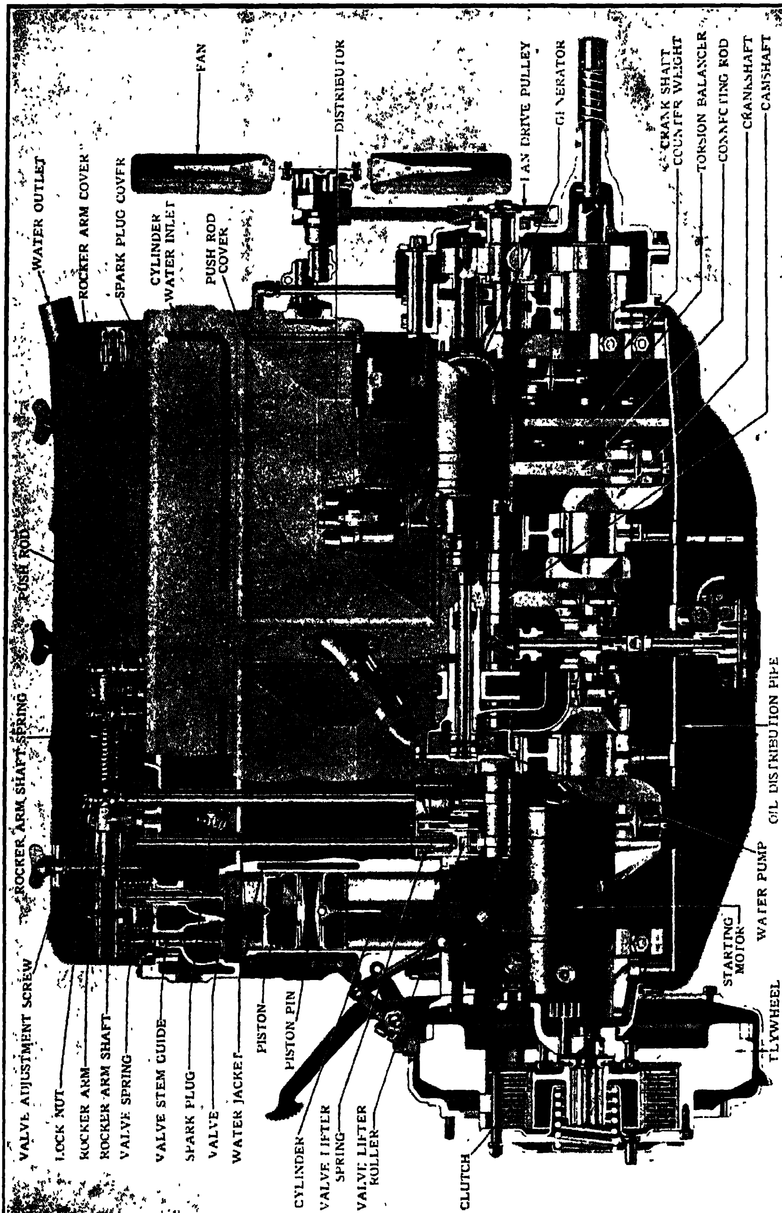


FIG. 66.—Interior Construction of the Engine. (Buick, 1928.)

crank case, which is fastened to the frame of the car, supports the cylinders and encloses the crank shaft and its bearings.

At their upper ends, the cylinders have two openings, closed by poppet valves. One of these communicates with the exhaust system and the other with the intake manifold and carburetor. The valves are opened and closed at the proper intervals in the cycle by rocker arms and push rods actuated by the cam shaft, which is geared to the crank shaft and which runs at one-half the crank-shaft speed. Each of the valves is opened and closed once for every two revolutions of the crank shaft. The cam shaft carries another gear which drives the oil pump, located in the lower half of the crank case.

Spark plugs project into the combustion space at the upper ends of the cylinders and serve to ignite the gas after it is compressed.

A double wall or water jacket entirely surrounds the upper part of the cylinders, and the water is kept constantly circulating through the space between the two walls by means of the water pump, which is attached to the crank case and is driven by another shaft geared to the cam shaft. The pump shaft usually runs one and one-half times as fast as the crank shaft and in some cases drives the generator through a coupling at the end.

How the Engine Operates.—The power of the engine is produced by burning or exploding charges of gas in the cylinders above the pistons. The resulting pressure forces the pistons downward and causes the crank shaft to rotate. In the 4-stroke-cycle motor it takes four strokes of the piston, or two complete revolutions of the crank shaft, for each explosion or working stroke in any one cylinder. This will be better understood by reference to the cycle diagram shown in Fig. 67.

As is fully explained on the following pages, internal-explosion engines are designed to perform two or four stroke-cycles per power stroke.

Horsepower.—The horsepower of explosion engines is usually indicated as the S. A. E. rating determined by the following formulæ:

For 4-stroke-cycle—H.P. $= \dfrac{D^2 \times N}{2.5}$.

For 2-stroke-cycle—H.P. $= \dfrac{D^2 \times N}{1.5}$.

D—cylinder bore in inches.

N—number of cylinders.

The results obtained by the use of these formulæ will vary greatly with the actual or brake horsepower. These serve to give a simple basis of comparison between engines of similar type and construction.

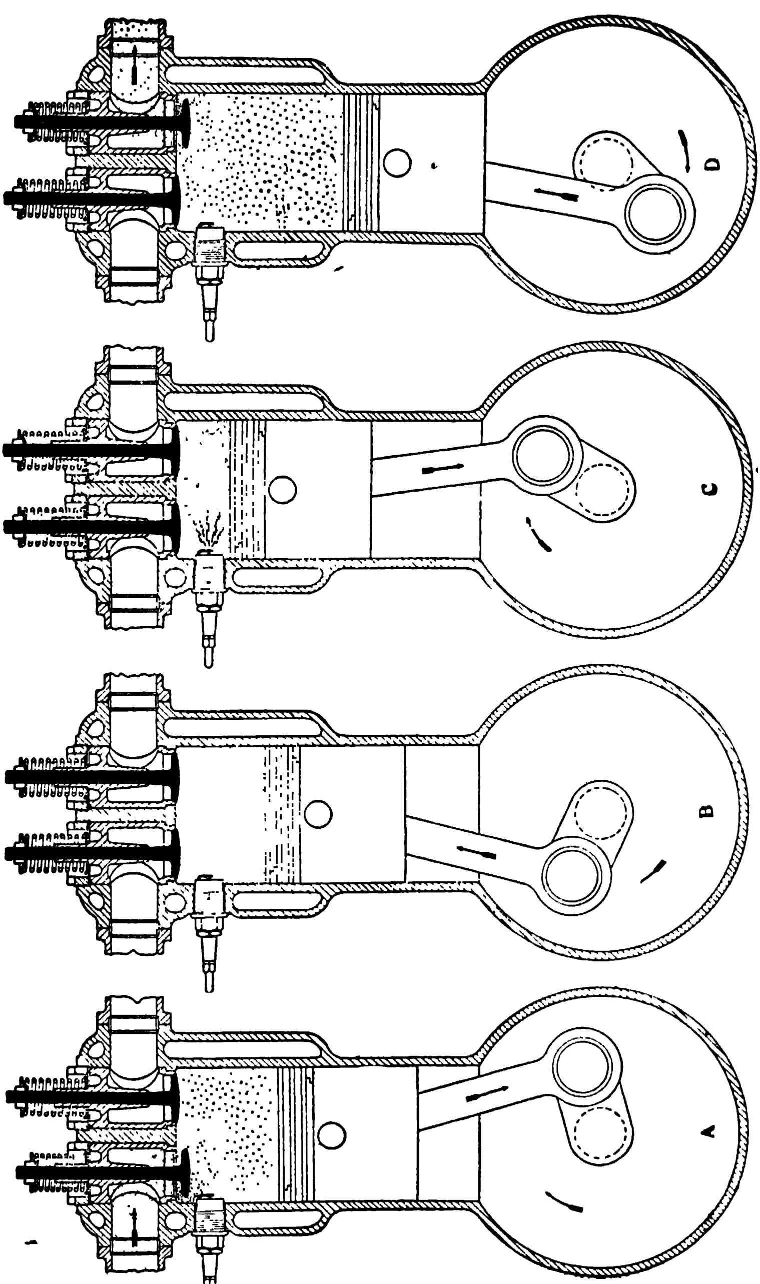


FIG. 67.—Cycle Diagram.

Cycles.—In the 4-stroke-cycle engine, as the piston starts down on the first stroke of the cycle (see *A*, Fig. 67), the inlet valve is opened. The downward motion of the piston tends to create a vacuum in the cylinder, and this vacuum draws in a charge of fresh gas from the carburetor through the open intake valve.

When the piston has reached the bottom of its stroke and starts back, as in *B*, the intake valve closes and the piston compresses the gas it has drawn into the combustion chamber.

As the piston reaches the end of its upward stroke, as in *C*, the compressed gas is ignited by an electric spark which occurs at the points of the spark plug. The resultant explosion forces the piston downward on the working stroke. It is this power stroke which turns the crank shaft. On all other strokes of the 4-stroke-cycle engine the crank shaft moves the piston.

On the return upward stroke of the piston *D*, the exhaust valve is opened, and the piston pushes the burned gas out through the exhaust pipe, leaving the cylinder empty and ready for the beginning of a new cycle.

It is apparent from this description that only one stroke out of the four is a working stroke in any one cylinder, but as the engine (Fig. 66) has six cylinders, the crank shaft actually receives three power impulses every revolution. Where a gear ratio of 4 to 1 is used in the rear axle the rear wheel would receive twelve power impulses every revolution.

The term *cycle* means a complete operation of events in some regular order. In the foregoing description it means a complete round of intake, compression, power, and exhaust strokes.

The operation of the 2-stroke-cycle engine is illustrated in Figs. 68 to 74, inclusive. (By permission of Tidewater Oil Co.)

The 2-cycle, 2-stroke type of internal combustion engine is used to a limited extent as the motive power of automobiles, but to a much greater extent for the propulsion of motor boats. Two systems of distribution, chiefly, are in use.

The Two-port Engine.—Figure 68 represents a piston *A* working within a cylinder *B* and connected to a crank *D* which imparts a reciprocating motion to it through the connecting-rod *C*. The 2-stroke-cycle engine usually contains neither inlet nor exhaust valves, the piston itself performing all the functions of the latter. A passageway or duct *E* opens into the cylinders and connects them with the crank case. An exhaust port *F* leads from the cylinder to the open air. A carburetor, or other mixing device, *G*, is attached to and opens into crank case *H*. A check valve, often combined with the carburetor, admits the explosive

mixture into the crank case, and prevents its escape during compression within the crank case. A projection or deflector *I* on the piston directs the inlet gas upward toward the head of the cylinder, thus avoiding a loss of the fresh charge with the exhaust gases rushing out at *F*.

The dimensions of the crank case are reduced to the smallest possible volume in order to afford compression of the explosive mixture within the crank case when the piston descends.

The fundamental difference between the operations of the 4-stroke-cycle and 2-stroke-cycle internal-combustion engines should be borne in mind. In the 4-stroke-cycle engine all operations take place separately within the cylinder *above* the piston, whereas in the case of the 2-stroke-

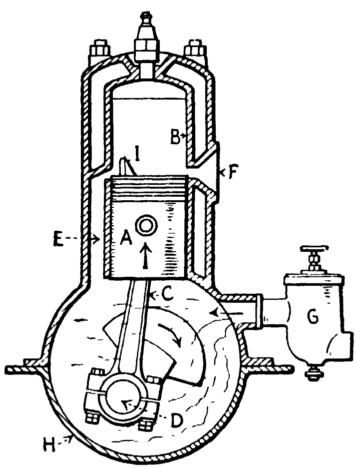


FIG. 68.—The Two-port Two-cycle Engine. (Inlet Stroke.)

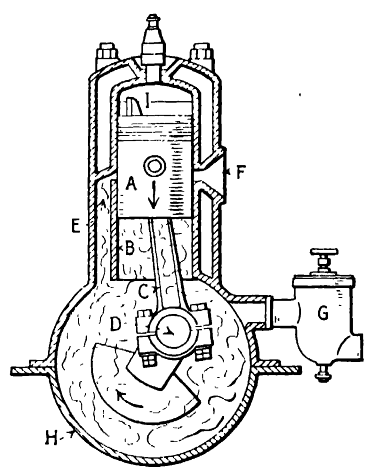


FIG. 69.—Crank-case Compression Stroke.

cycle engine, be it of the two-port or three-port types, the operations take place on *both sides* of the piston: that is, within the cylinder and within the crank case. Two operations occur at each stroke, compared to one operation in the 4-stroke-cycle engine. An explosion takes place and power is delivered once every two piston strokes or one revolution.

The operations in a two-port, 2-stroke-cycle engine are as follows: As the engine turns and the piston ascends within the cylinder (Fig. 68) the exhaust and inlet ports are closed and the explosive mixture is drawn into the crank case through the carburetor and check valve. This is the crank-case inlet stroke.

When the piston descends (Fig. 69) the explosive mixture is compressed within the crank case. At the lowest position of the piston in

the cylinder the inlet passageway is uncovered and the compressed charge imprisoned within the crank case escapes into and fills the cylinder.

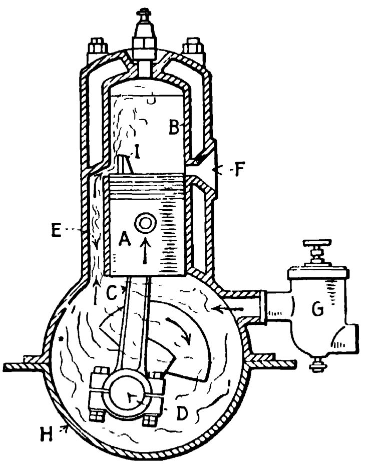


FIG. 70.—Cylinder Compression Stroke (Crank-case Intake.)

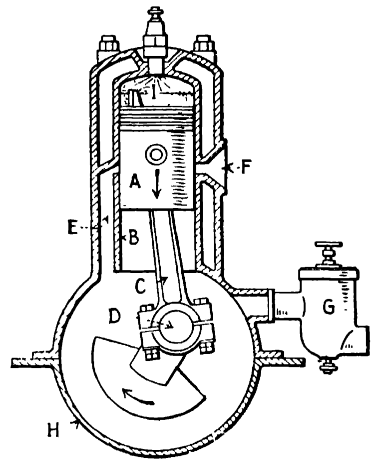


FIG. 71.—Power Stroke. (Crank-case Compression.)

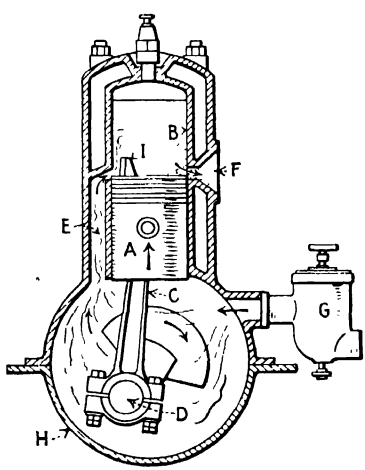


FIG. 72.—Exhaust and Intake.

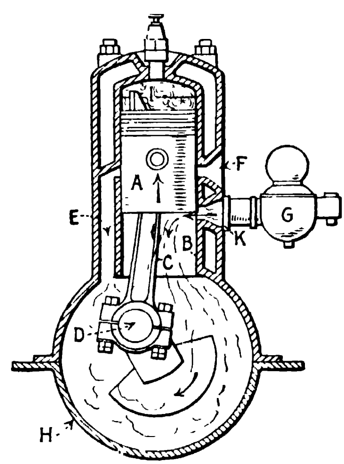


FIG. 73.—Crank-case Inlet Stroke. (Cylinder Compression.)

The piston again ascends, closing the inlet and exhaust openings, and compresses the charge within the cylinder, at the same time drawing the new charge into the crank case. (Fig. 70.)

At the top of the stroke (Fig. 71) the charge is ignited and the exploded gases drive the piston downward, delivering the power and compressing the new charge within the crank case.

At the end of the power stroke (Fig. 72) both the inlet and exhaust openings are uncovered. The burned gases escape through the exhaust port, and simultaneously the fresh charge entering the cylinder from the crank case through the inlet passageway strikes the deflector and is directed toward the top of the cylinder. This rapid inrush of the new charge aids in scavenging and in driving out the burned gases through the exhaust port. Cylinder compression and crank-case depression again take place as the piston ascends and covers the inlet and exhaust openings. From this point the cycle of operations is continuously repeated.

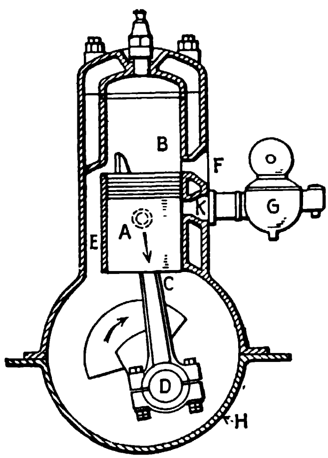


FIG. 74.—Power Stroke. (Crank-case Compression.)

The Three-port Engine.—In the three-port engine the third port *K*, leading from the carburetor to the crank case, is closed by the piston before the crank-case compression stroke, and no check valve between the crank case and the carburetor is necessary, as in the two-port engine.

The operation of the three-port engine differs somewhat from that of the two-port. As the piston ascends on the inlet stroke an increasing vacuum is created within the crank case until the lower part of the piston uncovers the third port and thus allows the inrushing mixture from the carburetor to fill the crank case. (Fig. 73.)

As the piston descends the third port is again covered and the explosive mixture is compressed within the crank case. At the lowest position of the piston in the cylinder (Fig. 74) the inlet passageway *E* is uncovered and the compressed charge escapes into the cylinder.

In all other respects the cycle of operations within the cylinder and the crank case of a three-port engine is exactly the same as in the two-port engine.

Valves and Valve Timing.—Practically all automotive engines of to-day are of the 4-stroke-cycle type and are equipped with both intake and exhaust valves. These valves are mechanically operated by a cam shaft and valve mechanism consisting of push rods and rocker arms, depending upon the design of the engine.

The opening and closing of the valves in time with the position of the piston in the cylinder is known as valve timing. Most engines have two valves to each cylinder: the inlet valve, which admits the fuel mixture into the cylinder; and the exhaust valve, which opens to let the burned gases out. Each of these operations must be very accurately timed to a very small fraction of a revolution of the flywheel in order that the engine may give its maximum power. The cams on the cam shaft are correctly machined and spaced at the factory after careful calculation and experiment. The cam shaft (Fig. 12*c*, 132 p.) is geared to the crank shaft, and unless removed and replaced in an incorrect position it must revolve in time with the correct position of the valves. The only case in which it is necessary for the repairman to "time valves" is where the timing gears or chain sprockets are unmarked and are not correctly meshed. Cases of this kind rarely come into a repair shop, so that if each time the gears are removed care is taken to note the manufacturer's marking and the parts are replaced in the same relative position, the timing of valves becomes a job for the manufacturer and not for the repairman.

Different makes have slightly different timing specifications; hence the repairman should consult the manufacturer's instruction manual for specific directions for the few valve jobs which may come to him for timing.

Pistons.—Pistons receive the force of the expanding gases and, being free to move, transmit this force to the connecting rod and crank shaft. The total force exerted on the connecting rod is equal to the product of the average pressure in pounds per square inch times the area of the piston head.

In order that the pistons may not stick in the cylinders when heated, they are made with considerable clearance, and piston rings are used to maintain compression.

The modern tendency in design is to make the pistons as light as possible in the interest of speed and balance. Alloy or light-weight cast-iron pistons are now used in nearly every engine. Different types of pistons are shown in Fig. 9*e*, p. 124.

Piston Rings.—Cast iron has been used in the majority of piston rings. The function of the rings is to preserve compression in the cylinder. They are compressed and inserted in the cylinder to maintain a spring fit. This, together with the seal made by a film of oil, prevents the escape of the confined gases. Most pistons have three rings placed at the top, although some have one ring at the bottom of the piston.

Figure 75 shows a concentric piston ring in its groove. Since the ring itself is concentric with the groove, very small clearance may be

allowed between the back of the ring and the bottom of its groove. Small clearance leaves less space for the accumulation of oil and carbon deposits. The gasket effect of this ring is uniform throughout the entire length of its edges. This type of piston ring rarely burns fast in its groove. A large number of rings of different designs are manufactured. Some are designed for oil control and others as compression rings, as shown in Fig. 76.

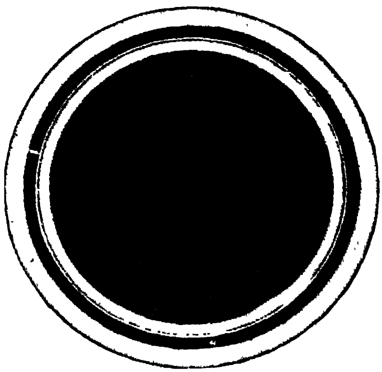


FIG. 75.—Concentric Piston Ring.

Figure 77 shows an eccentric ring assembled in the ring groove. It will be noted that there is a large space between the thin ends of this ring and the bottom of the groove. This empty space fills up with oil and, in the case of the upper ring, frequently is carbonized, restricting the action of the ring and nullifying its usefulness. The edges of the thin ends are not sufficiently wide to prevent rapid escape of gases past them. In a practical way this leakage means loss of compression and a noticeable drop in power. When new and properly fitted, very little difference can be noted between the tightness of the eccentric and concentric rings. After several months' use, however, a more rapid leakage will occur past the eccentric than past the concentric.

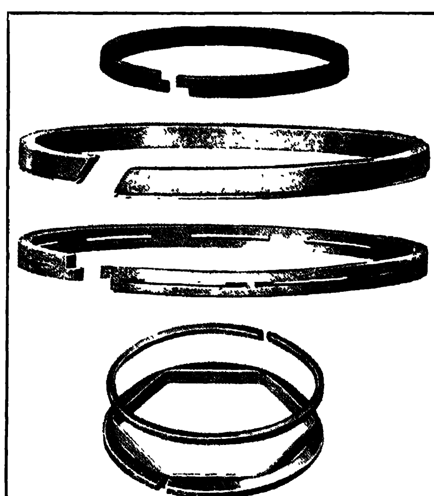


FIG. 76.—Types of Piston Rings.

If continuous trouble with the carbonization of cylinders and with smoking and sooting of spark plugs is experienced, it is a sure indication that mechanical defects exist in the engine, assuming, of course, that a suitable oil has been used. Such trouble can be greatly lessened, if not entirely eliminated, by the application of oil seal rings of any good make, properly fitted into the grooves of the piston.

A number of types of so-called " non-leak " rings are on the market. Most of these rings are made of two or three rings fitted together, each type having a different combination. All of them are designed to retain compression and to increase the power of the engine.

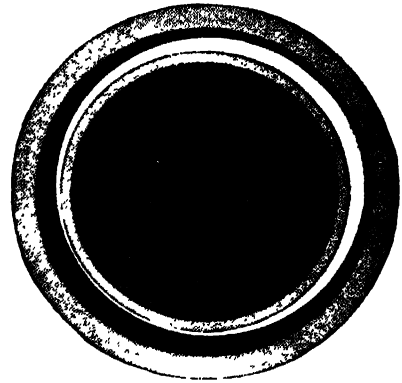


FIG. 77.—Eccentric Piston Ring. (Top View.)

Cylinders and Types of Engines.—Most gas-engine cylinders are constructed of cast iron, as this material has the ability to withstand most successfully the warping effects of high temperatures.

Cylinders are usually known as single, in pairs, or " in block " (*en bloc*), depending upon the method of casting. Most engines are now cast " in block." They are also known as L, ell-head, T, tee-head, I, eye or valve-in-the head types, depending upon the shape of the combustion head and the method of valve construction. The tendency toward casting the cylinders " in block " is made in the interest of better

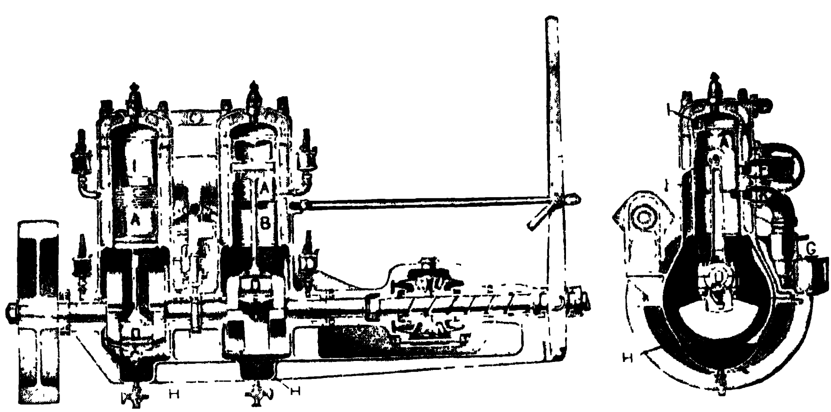


FIG. 78.—Two-cycle—Two-cylinder Engine. (Tidewater Oil Co.)

alignment, of less space, of water and hose connections, and of intake and exhaust manifolds as well as a reduction of noises by inclosing moving parts.

The following classification includes about all of the different types of cylinders which are in common use to-day:

1. Number of cylinders.
   (*a*) One-cylinder.
   (*b*) Two-cylinder (see Fig. 78).
   (*c*) Multi-cylinder (see Fig. 79).
2. Cycles.
   (*a*) Two-stroke-cycle (see Fig. 78).
   (*b*) Four-stroke-cycle (see Fig. 80).
3. Method of cooling.
   (*a*) Water-cooled (see Fig. 170, p. 491).
   (*b*) Air-cooled (see Fig. 173, p. 494).
4. Valve arrangement.
   (*a*) Valve in the head (see Fig. 4*a*, p. 107).
   (*b*) Tee-head (see Fig. 83).
   (*c*) Ell-head (see Fig. 2*d*, p. 103).
   (*d*) Sleeve valve (see Fig. 81).

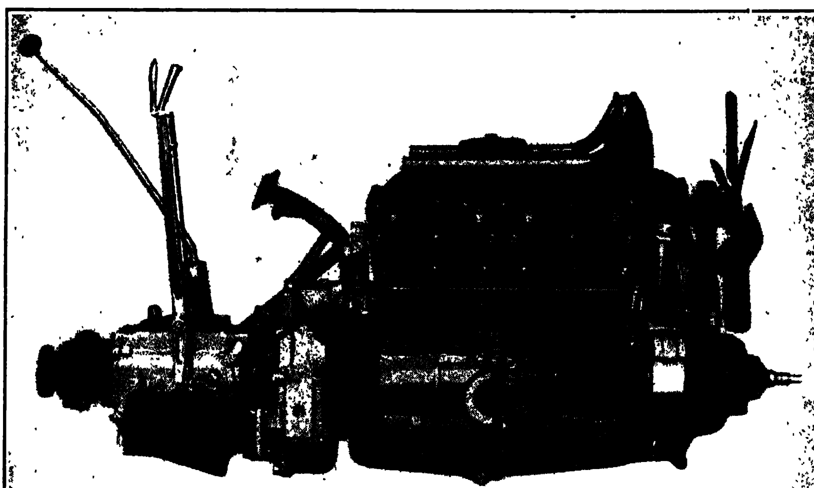


FIG. 79.—Eight-cylinder, V-type Engine. (Cadillac.)

The relative advantages of the different types are problematical and concern the maker or engineer much more than the repairman or owner. Part One covers fully the several repair jobs as applied to the different types.

Connecting Rods.—Most connecting rods are of drop-forged I-beam construction with two cap bolts on the crank-shaft end. In some engines an aluminum alloy rod is used.

The bearings at the crank-shaft end are of very great importance since they receive the force of the explosion of gas. They must be con-

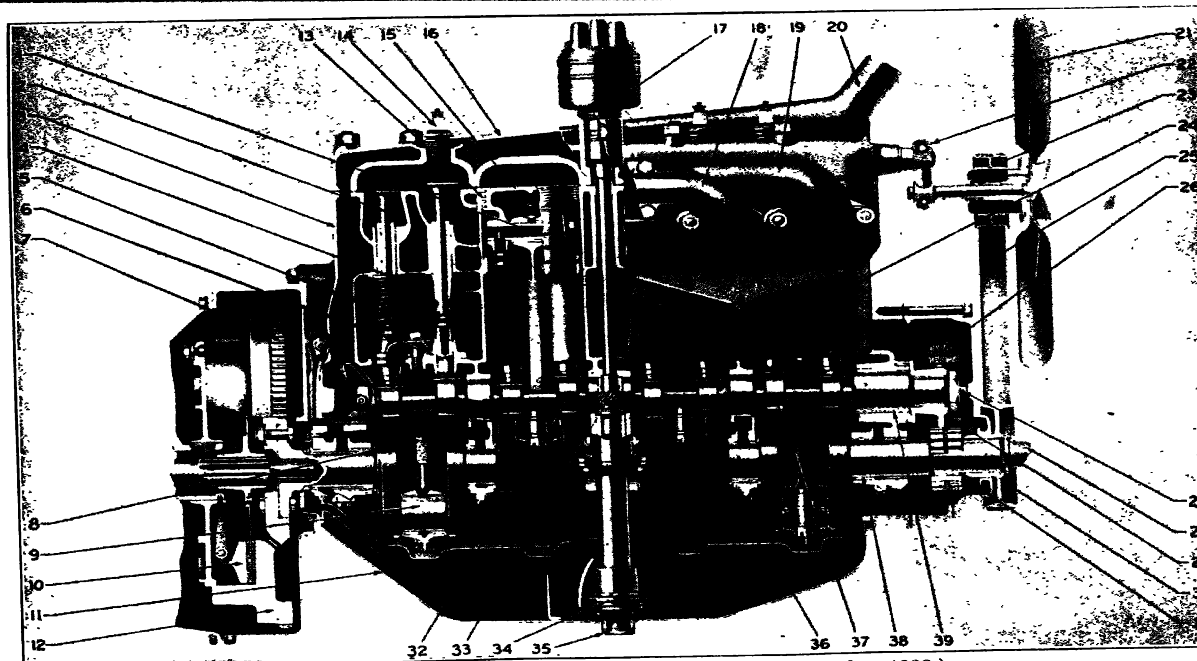


Fig. 80.—Four-stroke-cycle Four-cylinder Engine. (Dodge, 1928.)

1 Piston pin
2. Valve
3 Cylinder block
4. Valve spring
5. Valve lifter
6. Valve-lifter guide
7. Flywheel starting gear
8. Connecting rod
9. Crank shaft
10. Clutch
11. Oil pan
12. Flywheel
13. Piston rings
14 Spark plug
15. Piston
16. Cylinder head
17. Ignition unit
18. Intake manifold
19. Exhaust manifold
20. Water outlet
21 Fan
22. Fan bracket
23 Fan pulley
24. Valve spring cover
25. Fan belt
26. Cam shaft and generator driving chain
27. Cam-shaft thrust plunger
28. Starting crank jaw
29. Cam-shaft and crank-shaft sprockets
30. Fan-driving pulley
31. [illegible]
32. Cam.
33. Oil pump and ignition-unit driving gears
34. Oil pump
35. Oil-drain plug
36. Oil-pan pocket
37. Cam shaft
38. Crank-shaft front bearing
39. Cam-shaft front bearing

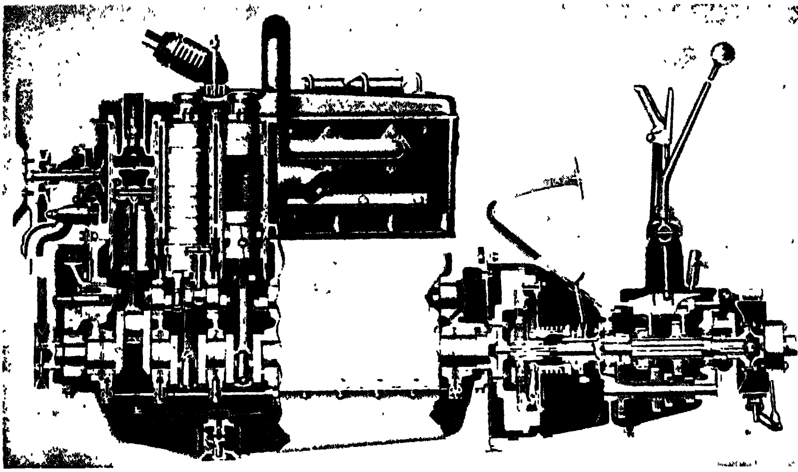


Fig. 81.—Sleeve-valve Engine. (Willys-Knight—Six.)

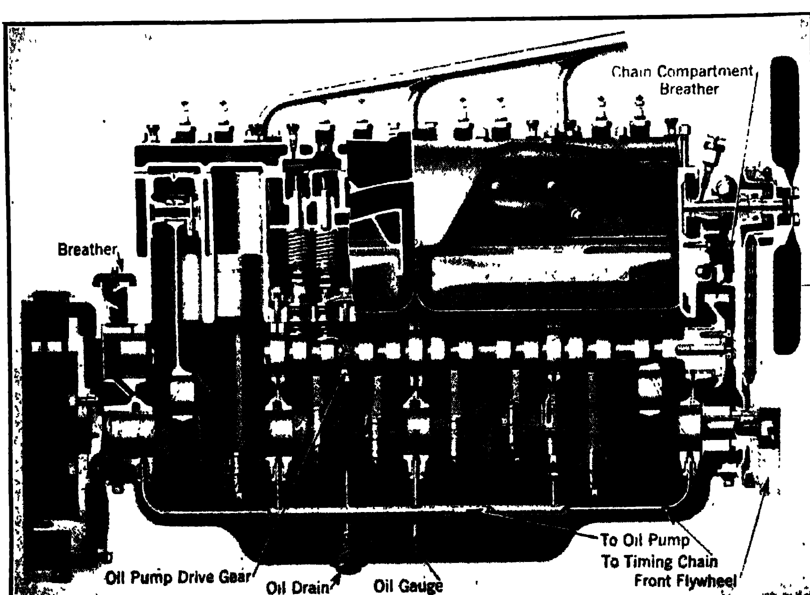


Fig. 82.—Straight-eight Engine. (Jordan.)

structured properly or a noisy engine will result. Usually they are made of a babbitt or composition metal bushing backed up with bronze. (See Jobs Nos. 6 and 7, Chapter II.) The bushings on the wrist-pin end are ordinarily made of bronze tubing fitted with a pressed fit. A hollow wrist pin admits oil to the bearing surfaces.

In V-type engines the bearings are fitted two on each crank pin. In some instances this means two bearings working side by side while in others one rod is split at the end into a fork with the other rod bearing fitted in between. (Fig. 6*d*, p. 113.) In the latter type the split bearing is fitted in the usual manner, with the inner rod using the outer surface as a crank-pin surface. In these types it is necessary to make the crank-shaft pins larger in diameter to make up for the reduced endwise surface.

Wrist Pins.—Piston or wrist pins join the connecting rod to the piston. Usually they are made of high-carbon steel, or low-carbon steel with a carbonized surface, ground to the correct size and highly finished. The pins are fitted into bronze bushings in the connecting rod, which are reamed to the pin with a push fit.

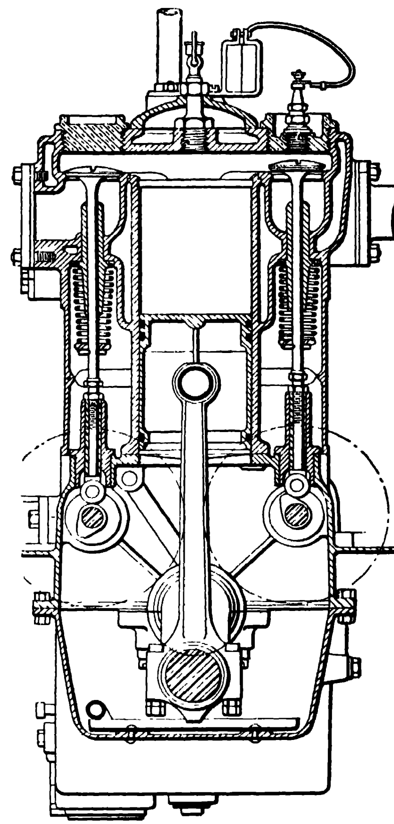


Fig. 83.—Section, "Tee" Head Engine.

Suitable locking devices are provided to keep the pin from moving endwise and thus scoring the cylinder walls. These devices consist of screws, locking pins, expansion plugs, or one of several other arrangements. (See Fig. 6*b*, p. 112.)

Cam Shafts.—Cam shafts are driven by gear or chain drives at one-half the speed of the engine. Practically all cam shafts are made of one piece, accurately machined, in order to time correctly the opening and closing of the valves. (See Figs. 12*a* and 12*c*, pp. 131 and 132.) It seldom happens that the repairman or owner is called upon to make repairs on this part except to replace the bearings.

Firing Orders.—In one- and two-cylinder engines there is no question as to the "firing order." In the modern automobile using four, six, eight, or twelve cylinders it is often necessary to know the order in which the cylinders are made to operate. This order is determined by the design of the cam shaft. The ignition system is timed to suit the valve action.

In four-cylinder engines two orders are possible. As a rule, the cylinders fire 1–3–4–2. Some engines,—the Model T Ford for instance,—fire 1–2–4–3.

A larger number of possible firing orders may be used in six-cylinder engines. In the early models the crank shaft was known as left-handed, owing to the arrangements of the crank pins. When 1 and 6 were up, 2 and 5 were going down, and 3 and 4 were coming up. Under this arrangement four firing orders were possible, of which 1–4–2–6–3–5 was most commonly used.

In newer engines the order is changed to a right-handed arrangement, so that when 1 and 6 are up 3 and 4 are going down and 2 and 5 are coming up. In this plan, also, the cylinder may have four possible orders, of which 1–5–3–6–2–4 is the customary arrangement.

In eight-cylinder, V-type engines there is a double four with the same possibilities for each block. The orders commonly used are:

(L. 1–3–4–2) or (L. 1–2–4–3)
(R. 2–1–3–4) (R. 3–1–2–4)

In the straight-eight engine there are two types of crank shafts used. The most popular type is known as the "split-four" shaft. Crank pins 3–4–5–6 are set at right angles to crank pins 1–2 7–8. There may be a number of different firing orders for this shaft, the most commonly used being the following:

1–6–2–5–8–3–7–4,
1–3–2–5–8–6–7–4,
1–5–2–3–8–4–7–6.

Twelve-cylinder engines are double sixes. While a number of possible orders may be used, most engines follow one or the other of the following:

(L. 6–3–5–1–4–2) or (L. 6–2–4–1–5–3)
(R. 1–4–2–6–3–5) (R. 1–5–3–6–2–4)

When the firing order on a given engine is unknown, consult the instruction manual furnished by the manufacturer or determine the order by the spark or by the valves.

At the present time some crank shafts are being equipped with vibration-eliminating devices. Two kinds are shown in Figs. 84–85, the Vibration Damper and the Harmonic Balancer.

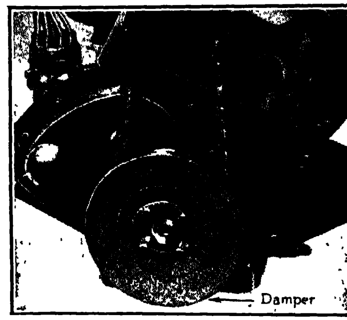


FIG. 84.—Vibration Damper.

Power Impulses.—The number of power impulses transmitted to the rear wheels by the explosions in the engine have much to do with the operation of the car. The illustration in Fig. 86 shows that with a reduction of 4 to 1 in the gear a one-cylinder engine delivers two power impulses each revolution of the rear wheel. If the number of cylinders is increased the number of impulses, is increased in the same ratio.

A twelve-cylinder engine shows a wide overlapping of the periods during which each impulse lasts and consequently there is an almost continuous impulse propelling the car, and less vibration results.

FIG. 85.—Harmonic Balancer.

Gaskets.—Gaskets made of soft metal or gasket material are inserted in joints to prevent oil, gas, air, or water leaks. A paper gasket is usually placed between the crank case and the base of the cylinder to prevent the oil from leaking out. Cork or composition gaskets are usually used between the upper and lower halves of the crank case and for the timing-gear cover.

Where the shape is circular, special gasket cutters may be used. In joints, such as intake and exhaust manifolds or spark plugs, special copper gaskets with asbestos inserts are used. Where great heat is encountered, asbestos gaskets must be used.

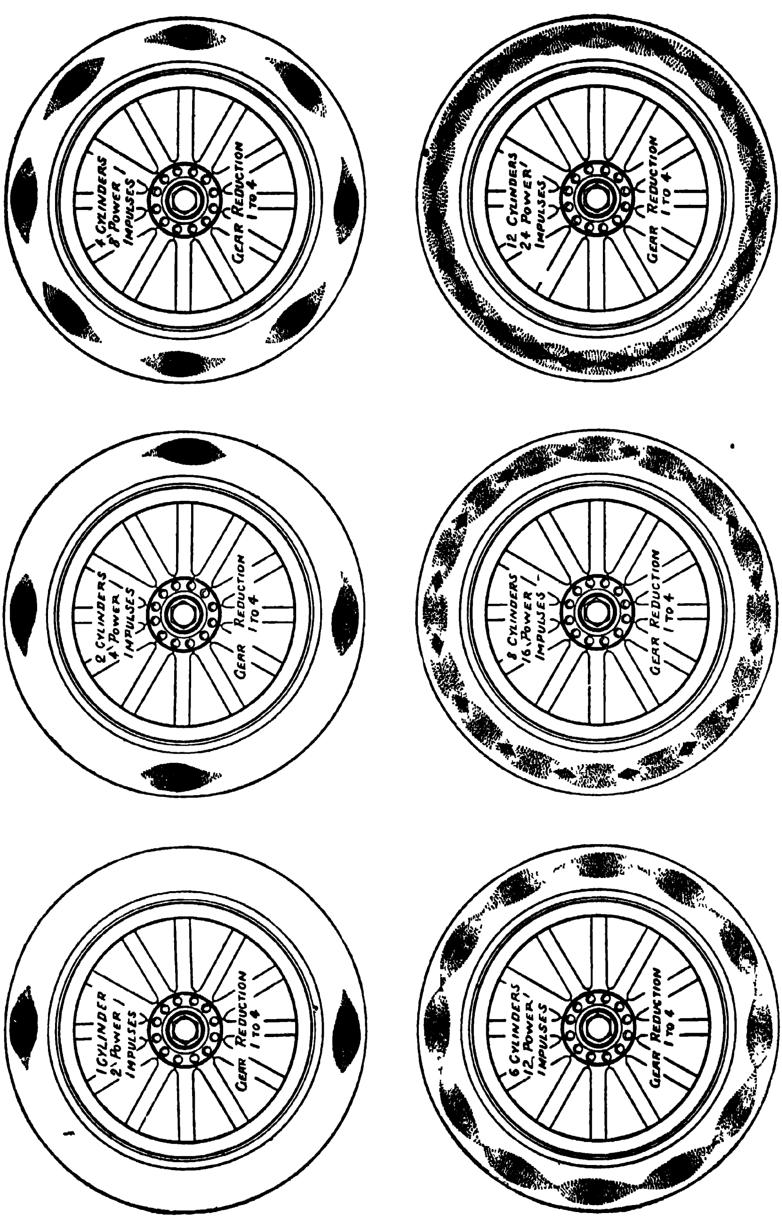


FIG. 86.—Power Impulses in One- to Twelve-cylinder Engines.

Manifolds.—The manifolds have received more attention in recent years than in the earlier engines. In the beginning the intake was long or short as the design seemed to make desirable. In modern types it has been shortened as much as possible, even to being entirely eliminated, so far as its external part is concerned, by connecting the carburetor directly to the engine block.

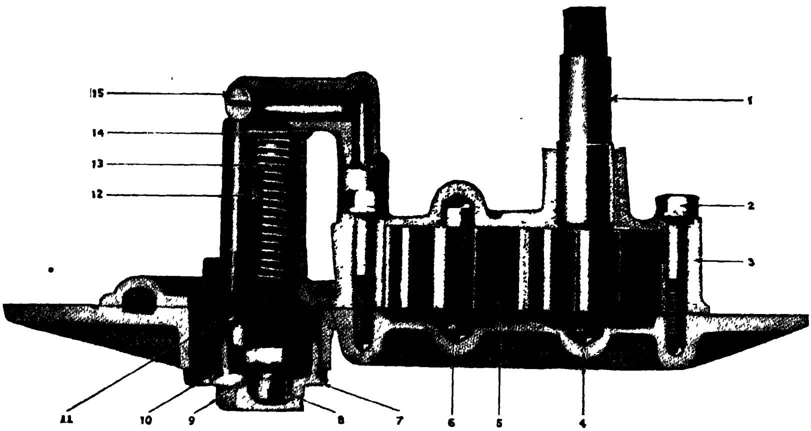


FIG. 87.—Oil Pump and Relief Valve.

It is necessary that the gas of to-day be preheated before entering the cylinders, and a short manifold not only can be kept warmer but also offers less chance for the gas to condense before reaching the cylinder.

To insure a more even operation of the cylinders, the distances from the carburetor to each cylinder should be the same. Various methods have been used to insure complete vaporization of the fuel. Some of these methods require special heating provisions for the intake manifold. In some types a part of the exhaust gases are caused to pass through a separate passageway in the intake; in others, special devices are located in the intake passageway.

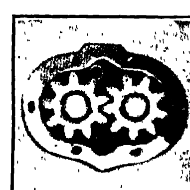


Fig. 87*a*.—Bottom view of Oil Pump.

The exhaust manifold also has been given much attention. It is desirable that the successive exhausts from the cylinders do not load up on each other and thereby create a back pressure. Certain manufacturers lay great stress upon their methods for eliminating this condition. In some eight- and twelve-cylinder engines two exhausts are used.

Oiling Systems.—Engine lubricating systems are the arteries through which the oil flows as it goes from point to point in its path of lubrication. Many different schemes for lubricating the engine internally have been devised. All of them may be classified either under the splash or the pressure system, or under a combination of the two.

Figure 88 shows the operation of the splash system, as used on the Model T Ford engine. The oil is poured into the filler tube and runs back into the lowest part of the oil pan, where the flywheel in its rotation picks up the oil adhering to it and drops it off into a tube which leads the

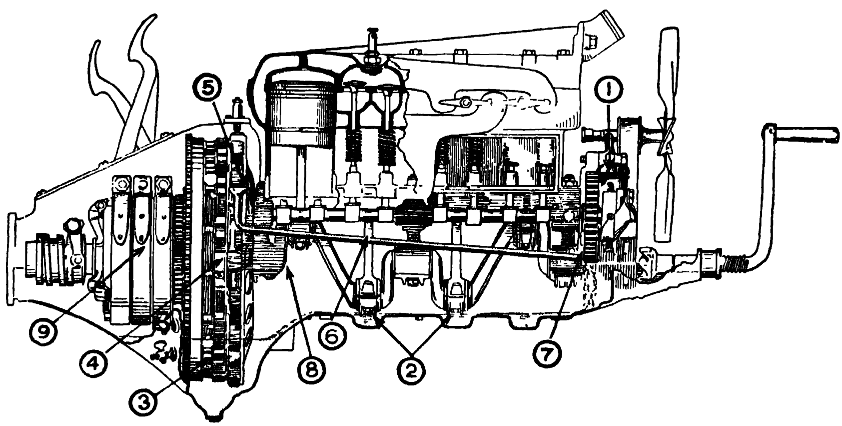


FIG. 88.—Ford Lubricating System. (Model T.)

1 Oil filler cap
2. Oil flows into splash troughs for connecting-rod dip
3 Oil reservoir near bottom of crank case
4 Flywheel acts as oil pump
5 Collecting funnel carries oil into header pipe
6 Oil header or distributing pipe
7 Oil projected to timing-gear train and drops to forward crank-case bottom
8 Rear cylinder lubricated by flywheel splash
9. Transmission gears, sleeves, and multiple disk clutch lubricated by flywheel splash.

oil to the timing gear case and then allows it to run back, filling up the connecting-rod troughs on its way to the lowest part of the oil pan. Other motors use either the full forced-feed or a combination of both. Figure 89 illustrates a forced-feed system.

Oil poured into the filler tube flows down into the oil pan, filling it up to a height indicated by the oil-level gauge on the right-hand side of the oil pan. From the pan or reservoir the oil is drawn up by the oil pump, which is driven by a vertical shaft from spiral gears on the cam shaft. The oil pump itself is surrounded by a fine screen so that all oil entering the system is thoroughly strained to remove the dirt or lint that might stop up the oil ducts and cause damage.

The gear pump, which at all times is submerged in the oil at the extreme bottom of the reservoir, draws the oil through the screen and forces it into a distributing pipe running the entire length of the crank case. From this pipe the lubricant is forced to each of the seven crank-shaft main bearings, keeping them constantly flooded when the engine is running. From the main bearings the oil is forced through holes in the crank shaft to the connecting-rod bearings.

Since at every revolution of the crank shaft these holes register with the leads from the distributing tube, an excess of oil is forced to the

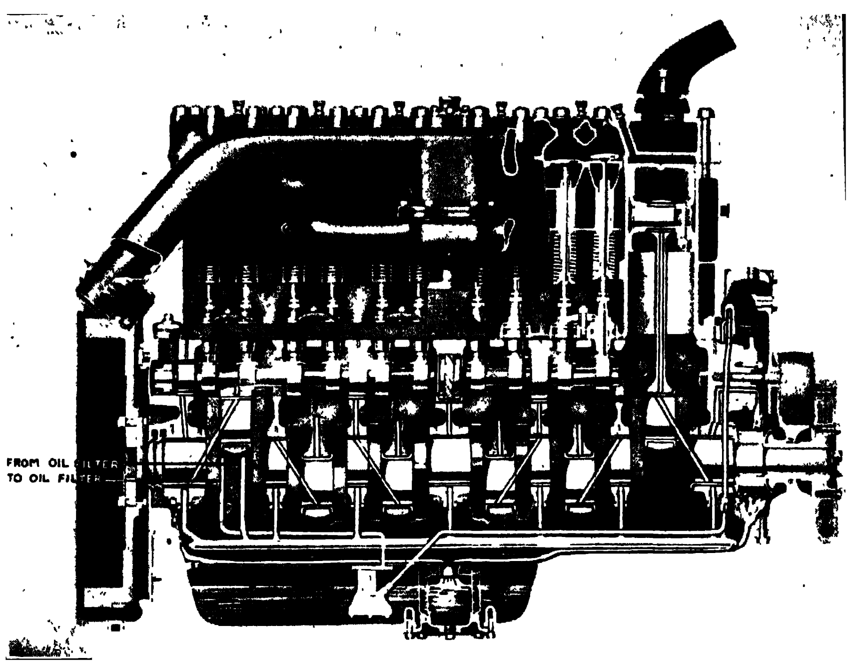


FIG. 89.—Forced-feed Oiling System.

connecting rods where it is thrown off in fine drops or mist on to the cylinder walls. A part of this spray is utilized for lubricating the cam shaft and the valve tappets. The oil is also forced through a duct to the timing gears in the front of the motor. This method of cylinder lubrication insures each cylinder's getting exactly the same amount of oil. The fact that the car is traveling up or down grade has no effect on the cylinder lubrication.

The pressure of the oil in the system is controlled by a spring and plunger valve located on the front end of the crank case. The periodical

changing of engine oil is of special importance in the care of the engine and in any event should be attended to at the completion of the first

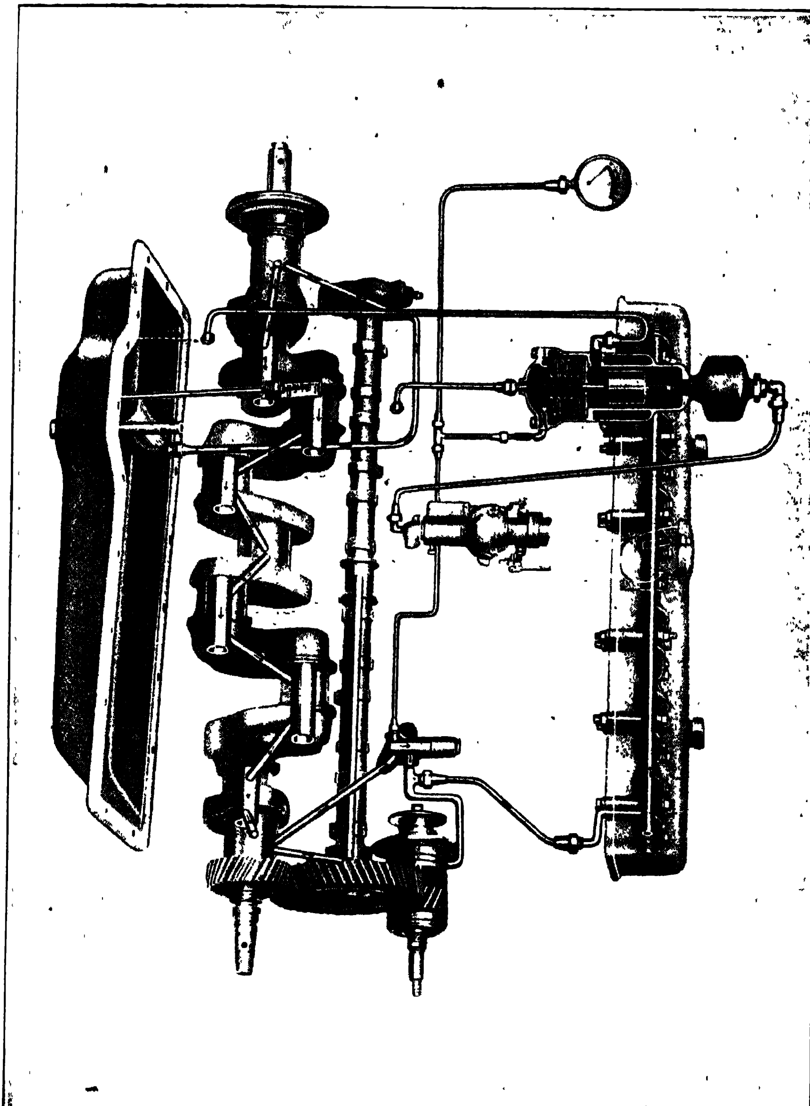


Fig. 90.—Forced-feed Lubrication. (Marmon 34.)

500 miles and every 500 miles thereafter unless the car is equipped with some type of oil purifier. During this period of service, fine particles of metal from cylinder walls, pistons, rings, bearings, and other moving

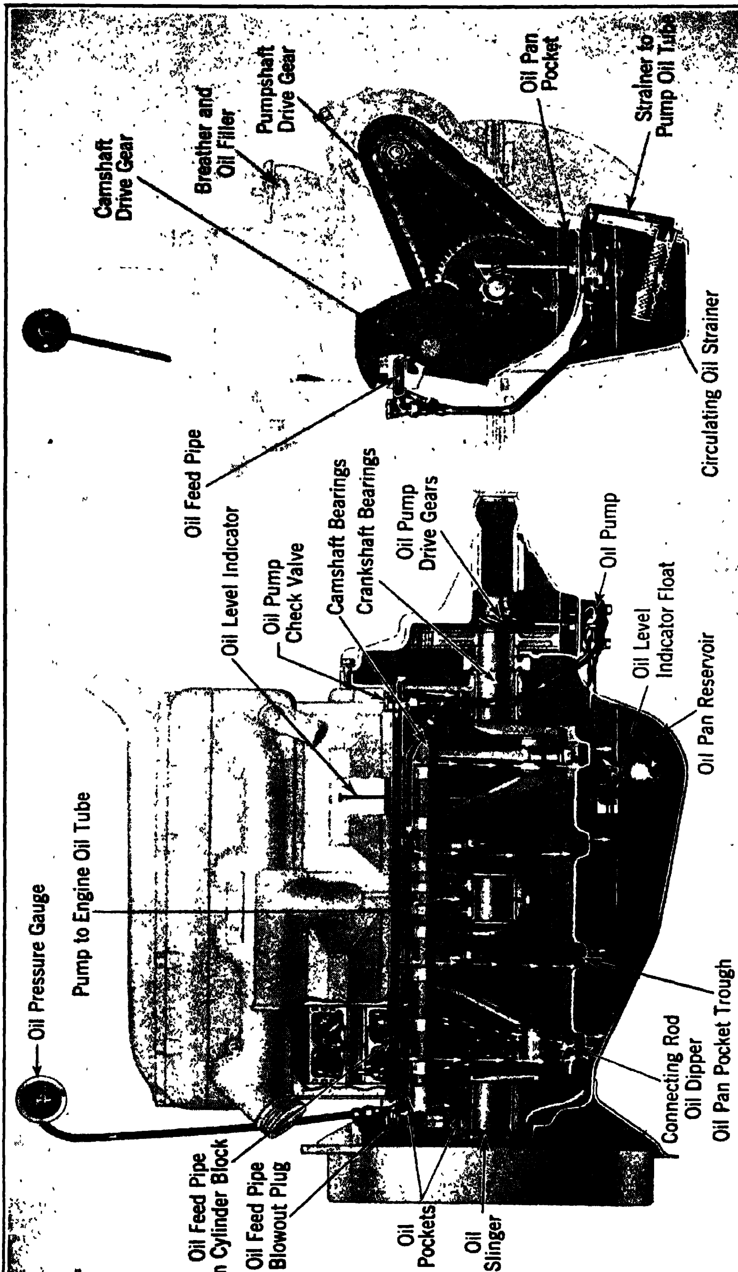


FIG. 91.—Splash and Pump Circulating Oiling System. (Dodge.)

parts will be set free and held in suspension in the oil. This reduces the lubricating qualities, which are further reduced by heat and by gasoline, a small percentage of which, owing to its present low grade, condenses in the combustion chamber before the motor is thoroughly warmed and seeps past pistons and rings into the oil reservoir. This low-grade gasoline has a more deleterious effect on the oil than any of the other items.

Figure 90 shows the oiling system used on the Marmon. It is of the forced-feed type. Figure 91 shows a combined splash and pump circulating system.

Oil is fed to the five crankshaft bearings and the timing gears by pressure, while the pistons and connecting rods are oiled by a splash. The oil is circulated by means of a vane pump located at the forward end of the engine.

Simplicity in Oiling Systems.—In general, the development of motor vehicles has been phenomenally rapid during the past decade. The tendency has been and is toward simplicity in design, which is obtained by employing the smallest permissible number of parts required to perform the various functions of engine operation. In no one line has this tendency toward simplicity been so strong as in the methods employed for lubrication.

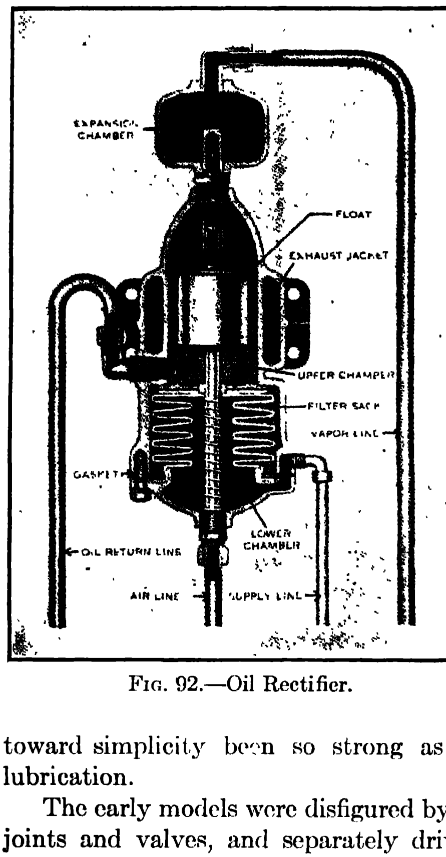


Fig. 92.—Oil Rectifier.

The early models were disfigured by a network of pipes, innumerable joints and valves, and separately driven lubricators, which in themselves were exceedingly complicated and liable to frequent disarrangement.

At the present time designers are striving further to simplify the methods of lubrication. As a matter of fact, there seems to be no good reason why one lubricating system should not be adopted as standard for all types of engines. Such simplification would mean increased

efficiency and lower upkeep cost. Users would have less difficulty in learning the details of a single system than in learning the unnecessarily complicated details of many systems.

Many engines are equipped with purifiers or oil rectifiers which remove the acid, moisture, and sediment from the oil. Figures 92 and 93 show two types.

Carbonization.—One of the most annoying sources of engine troubles is carbonization. When an excessive amount of carbon collects in the cylinders the engine overheats, misses fire, knocks because of excessive compression, and fires prematurely.

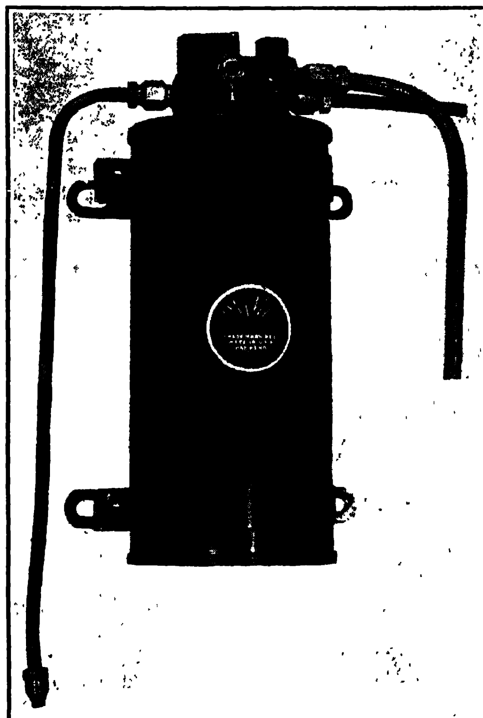


FIG. 93.—Oil Filter.

The owner who rarely drives at speeds exceeding 15 to 20 miles an hour and who uses his car for trips of a very few miles at a time never brings the engine up to an efficient temperature. Such owners are more troubled with excessive oil consumption, sooted plugs, carbon deposit, and smoking at the exhaust than are the owners who ordinarily drive at higher speeds and over longer distances.

In any engine that is continually driven at slow speed the vacuum in the combustion chambers at the beginning of the suction stroke is very high, owing to the fact that the throttle is always nearly closed. There is a tendency, therefore, for this vacuum to draw up the oily mist from the crank case, resulting in the troubles mentioned.

From this explanation it will be understood why the driver who is accustomed to traveling at a varying range of speed has less annoyance from these troubles than the habitually slow driver. The more rapid dipping of the connecting rod tends to distribute the oil to a better advantage, keeping the troughs at a more uniform level, and when short

spurts of speed are made, the heat burns any excessive carbon and thus has the effect of cleaning the plugs.

The removal of a spark plug affords an excellent opportunity to inspect the cylinder for excessive carbon deposits. If excessive carbon is found, the owner should be notified and his authority obtained for removing the carbon. It is obvious that an engine cannot be expected to operate satisfactorily if the cylinders are clogged in this manner.

The formation of carbon in the cylinders may be due to incomplete combustion of the gasoline or to the quality of the lubricating oil used, or both. When such a deposit is due to a poor grade of lubricating oil the difficulty may be overcome by the use of a better grade of oil, but when the formation is due to incomplete combustion of the fuel, the cause is usually of a mechanical nature. Leaky valves or pistons aggravate the conditions which cause carbon, because compression is thereby reduced and rate and completeness of combustion are impaired. Rapid and complete ignition is impossible at ordinary engine temperatures without proper and sufficient compression. A weak spark may also give similar results, although perhaps not to the same extent as poor compression.

Incorrect carburetor adjustments, especially those which will increase the amount of gasoline drawn into the cylinders, are also responsible for carbon formation, and the timing of the ignition has an important bearing on the same subject.

Poor compression rarely exists as a result of piston or piston ring trouble, but is more likely to be due to the carbon itself, which tends to accumulate on the exhaust-valve seat, preventing tight closing of the valve and causing subsequent escape of the charge during the compression stroke. The weak compression results not only in lack of power but also in a further deposit of carbon.

Grinding of the valves will therefore result in bettering conditions materially.

Engine Operation.—In operating the gas engine, always keep three general principles in mind:

1. *A Combustible Fuel.*—By a combustible fuel is meant a mixture of gas and air in a ratio which will permit of rapid burning or explosion when ignited by a spark or flame. Ratios of 1 to 8 of gasoline and air *by weight* begin to be explosive, and as the amount of gas is decreased it continues to explode until the mixture reaches a ratio of 1 to 22. A mixture of gasoline and air of 1 to 15 is the ratio commonly used.

Mixtures below a ratio of 1 to 8 are too rich to ignite, and those above 1 to 22 are too lean.

By volume the ratios vary from 1 to 5 of gasoline vapor and air to 1 to 15.

It is clear, then, that an engine may fail to run, on the one hand, because there is too much gasoline in the cylinders, or, on the other hand, because there is too little gas.

2. *Suitable Compression.*—As the mixture is compressed it becomes more explosive or easier to ignite; in fact, under certain critical temperatures the mixture may be ignited by compression.

3. *A Hot Spark.*—When the conditions given in 1 and 2 are satisfactory, a hot spark will ignite the compressed gases and the engine will operate.

The foregoing principles, if kept in mind, will always serve to aid in locating and tracing a trouble to its source. A process of elimination should be followed. For example, if the engine does not start, make your tests to locate the trouble in the order of simplicity. Is there gasoline in the tank? This may easily be determined. If not, you have at once located the trouble. If gasoline is found in the tank, is there a supply in the carburetor? If not, steps should be taken to locate the stoppage and to correct the trouble. Each possible source of trouble should be eliminated until the trouble is located. In most cases trouble of this kind can be located by simple tests without the use of hand tools.

Chapter IV on Trouble Shooting should be studied carefully to fix in mind the many different things which may produce certain results. A good plan is to " think twice " before starting to work with the tools and before beginning to remove and disassemble parts. When the engine appears to be in an operating condition, set the gear-shift control in neutral position, set the spark throttle to about one-third advance position, unlock the switch, turn the ignition button or lever to the " on " position, set the " air choke " to starting position, press down on the clutch pedal, and press the starting switch.

If the motor does not start in a few turns, release the starting pedal and inspect the controls to see that everything is set for starting, and repeat. In winter time more cranking is necessary, but even in cold weather the engine should start with twenty to thirty seconds' cranking.

Never continue to hold down the starter after thirty seconds as it will quickly discharge the battery. If the engine does not start, locate the trouble by referring to Job No. 6, Chapter IV.

Because of the presence of carbon monoxide, a poisonous gas, in the exhaust of the engine, *never run the engine for any length of time while the car is in a small closed garage.* Opening the doors and windows will lessen the danger considerably; but to run the car out of doors is the

safest, if adjustments are being made that require the operation of the engine.

Questions.

1. What is meant by 2- and 4-stroke cycles?
2. At what point in the series of cycles does the spark occur?
3. What three conditions are necessary to get an explosion?
4. What is an explosive mixture?
5. What are the explosive ratios of air and gas? By weight? By volume?
6. How is the fuel prepared for admission into the cylinder?
7. What is meant by " firing orders " ?
8. Upon what does the firing order of an engine depend?
9. What are the requirements of a good piston? Of piston rings?
10. What are the advantages and disadvantages of cylinders cast in block?
11. Describe the operation of a gas engine.
12. What is the object of compression?
13. What are the by-products of the average mixture after combustion?
14. What part of the air mixed with gas is used?
15. How is the power of a gas engine rated?
16. Is this method accurate for all designs?
17. What are the advantages of the " valve-in-head " engines?
18. What are the advantages of " tee " and " ell-head " engines?
19. What causes carbon in the cylinders?
20. What are the different oiling systems?

CHAPTER IX

LUBRICANTS AND LUBRICATION

LUBRICATION is of very great importance in the operation of any machinery and it is especially important in the operation of automotive equipment. The life and operation of the working parts depend upon the efficiency of the lubricating systems. The quality and quantity of the lubricant used are vitally important.

Figure 94 shows what points on a passenger car must be lubricated, and how frequently. Each manufacturer issues in his *instruction manual* similar instructions for his own make of car. The charts should be studied until attention to the lubricating system for the entire car becomes automatic. It is not enough to keep on pouring oil into the crank case every time gasoline is purchased, for every moving part needs regular inspection and renewal of lubricants.

The Object of Lubrication.*—Lubrication is necessary because of the existence of friction. Friction is a loss of power or energy by the rubbing of one body or surface over another. It is the resistance to relative motion of surfaces in contact and depends upon the nature and roughness of the surfaces. Friction is a conversion of *useful* energy into useless heat, accompanied by wear. There are two kinds of friction: static (starting), and kinetic (moving). A distinction must be made between friction of solids and friction of fluids; the latter represents only a small fraction of the former. Friction can never be eliminated entirely in any mechanism, but by making use of suitable lubricants, properly applied, it can be reduced to a minimum.

Lubrication is the introduction of a smooth fluid or semi-fluid substance, such as oil or grease, between two moving surfaces to prevent solid friction, that is, their coming into direct metallic contact. All bearing surfaces, however smooth to the naked eye or touch, are microscopically rough, and unless some medium is introduced which will cover these irregularities and fill up the depressions, the surfaces will interlock and give rise to friction, heat, and rapid wear. When moving parts are separated by a lubricant, friction takes place within the liquid itself,

*From Veedol. By permission of the Tidewater Oil Company.

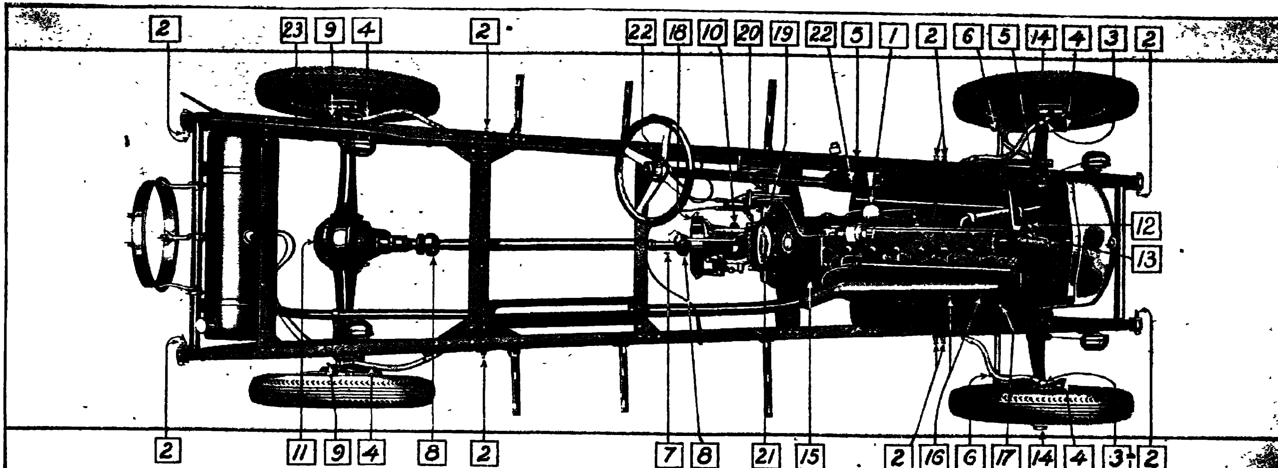


FIG. 94.—Typical Chassis—Lubricating Chart. (Diana 8).

1. **Engine.**—Filler opening. Add Mobiloil " A " summer and " Artic " winter, daily, as needed, to maintain correct level.
2. **Spring Shackle Bolts.**—Twelve Alemite fittings. Add engine oil weekly or every 250 miles
3. **Steering-Knuckle Pivots.**—Four Alemite fittings. Use engine oil weekly or every 250 miles.
4. **Brake Band Anchor Pins.**—Four Alemite fittings. Use engine oil weekly or every 250 miles.
5. **Steering Gear Connecting Rod** (Drag-Link).—Two Alemite fittings. Use engine oil weekly or every 250 miles.
6. **Steering-Knuckle Tie-Rod.**—Two Alemite fittings. Use engine oil weekly or every 250 miles
7. **Propeller Shaft Slip Joint.**—One Alemite fitting. Use engine oil weekly or every 250 miles.
8. **Universal Joints.**—Two plugs. Fill housings every 1000 miles with high-grade gear lubricant, such as Gargoyle Mobiloil " C ".
9. **Rear Wheel Bearings.**—Two Alemite fittings. Use Mobiloil " CC " every 1000 miles.
10. **Transmission.**—One plug at side of case. Every 1000 miles remove plug and refill to level of filler-hole with Gargoyle Mobiloil " C ".
11. **Differential.**—Plug, in back cover plate. Every 1000 miles remove plug and refill to level of opening with Gargoyle Mobiloil ' C ".
12. **Fan.**—Two grease cups. Mobilubricant weekly or every 250 miles.
13. **Water Pump.**—Two grease cups. Mobilubricant weekly or every 250 miles.
14. **Front Wheel Bearings.**—Two hub caps. Mobilubricant inside caps every 2000 miles.
15. **Starting Motor.**—No lubrication necessary.
16. **Generator.**—Two oil cups. Apply 8 to 10 drops of engine oil every 500 miles.
17. **Distributor.**—One oil cup. Apply 8 to 10 drops of engine oil every 500 miles. Wipe breaker cam with vaseline at same time.
18. **Transmission Brake Connections.**—Add a few drops of engine oil monthly.
19. **Brake Pedal Bearing.**—One hole. Add a few drops of engine oil monthly
20. **Clutch Shaft Bearing.**—Add a few drops of engine oil monthly.
21. **Clutch Throwout Yoke.**—Add a few drops of engine oil monthly.
22. **Steering Gear.**—One plug or Alemite fitting. Refill housing every 2000 miles with Gargoyle Mobiloil " CC ". Put 4 or 5 drops of engine oil in steering wheel spider weekly.
23. **Spring Leaves.**—Jack up car and slush with oil or insert grease whenever springs begin to squeak.

between its particles and the contact surfaces. A copious circulation of oil through bearings carries off the friction heat generated and makes possible conditions requisite for efficient lubrication.

Loss of Lubricating Qualities.—In cold weather it is difficult to vaporize the ordinary commercial gasoline and sometimes almost impossible to start the engine. The carburetor is equipped with a dash control or air choke which enables the operator when starting the engine to close the air-inlet passage. This permits a rich mixture of gasoline to enter the cylinders and makes starting less difficult. However, using this adjustment too frequently has a tendency to deposit large quantities of gasoline in the oil reservoir, which, of course, will seriously interfere with proper lubrication.

During cold weather, when the motor is running erratically, is slow to warm up, lacks power, and shows symptoms of unsatisfactory operation, if the operator will draw off all the oil in the reservoir he will undoubtedly find, instead of pure cylinder oil, a solution adulterated with a large percentage of gasoline, which interferes with proper lubrication.

Loss of the lubricating qualities in an oil will bring many unsatisfactory conditions for which there is no apparent cause. These conditions are usually difficult for the inexperienced operator to comprehend. Some of the difficulties which may be a direct result of impaired lubricating qualities of the oil are as follows:

1. Hard starting.
2. Premature piston wear.
3. Premature cylinder wear.
4. Overheating.
5. Loss of compression.
6. Connecting-rod bearings burning out.
7. Crank-shaft bearings burning out.
8. Excessive gasoline consumption.
9. Smoking, due to increased oil level.
10. Excessive carbonization.

Selecting the Lubricant.—The suitability of an oil for the proper and efficient lubrication of all internal-combustion engines is determined chiefly by the following factors.

1. Type of cooling system (operating temperatures).
2. Type of lubricating system (method of applying oil to the moving parts).
3. Rubbing speeds of contact surfaces.

Were the operating temperatures, bearing surface speeds, and lubrication systems identical, a single oil could be used in all engines with equal satisfaction. The only change necessary in viscosity would be that due to climatic conditions. As engines are now designed, only three grades of oil are necessary for the lubrication of all types with the exception of the Knight, the air-cooled, and some engines which run continuously at full load. In the specification of engine lubricants the load carried by the engine should be carefully considered. Engines are designed for variable loads as follows:

Full-load engines:

1. Marine.
2. Racing automobile.
3. Aviation.
4. Farm tractor.
5. Some stationary.

Variable-load engines:

1. Pleasure automobile.
2. Commercial vehicle.
3. Motor cycle.
4. Motor Bus.
5. Some stationary.

Kinds of Lubricants.—When the moving parts operate at high speeds, oils of a suitable grade are the most satisfactory lubricants. A thin coating of oil clings to the surface and prevents the rougher metal surfaces from coming into full contact. This coating should be as thin as possible to prevent additional fluid friction. Oils flowing through a bearing absorb heat and carry away loose particles of dirt and metal.

All lubricants may be classified into three general groups: (1) Fluid, (2) plastic, and (3) solid; or oils, greases, and certain solids, such as graphite, soapstone, and mica.

A large number of products are on the market and may be obtained at service stations. It is advisable to consult the manufacturer's instruction book for the best grade and quality to use on any particular car. When the grade and quality have been determined, do not make frequent changes.

Oils.—The qualities requisite for a satisfactory gas-engine oil are based on a compromise between its various physical properties. The viscosity should be sufficient to give good lubrication at the highest probable temperature of the bearings and cylinder walls. The viscosity should not be so great at ordinary temperatures as to obstruct the

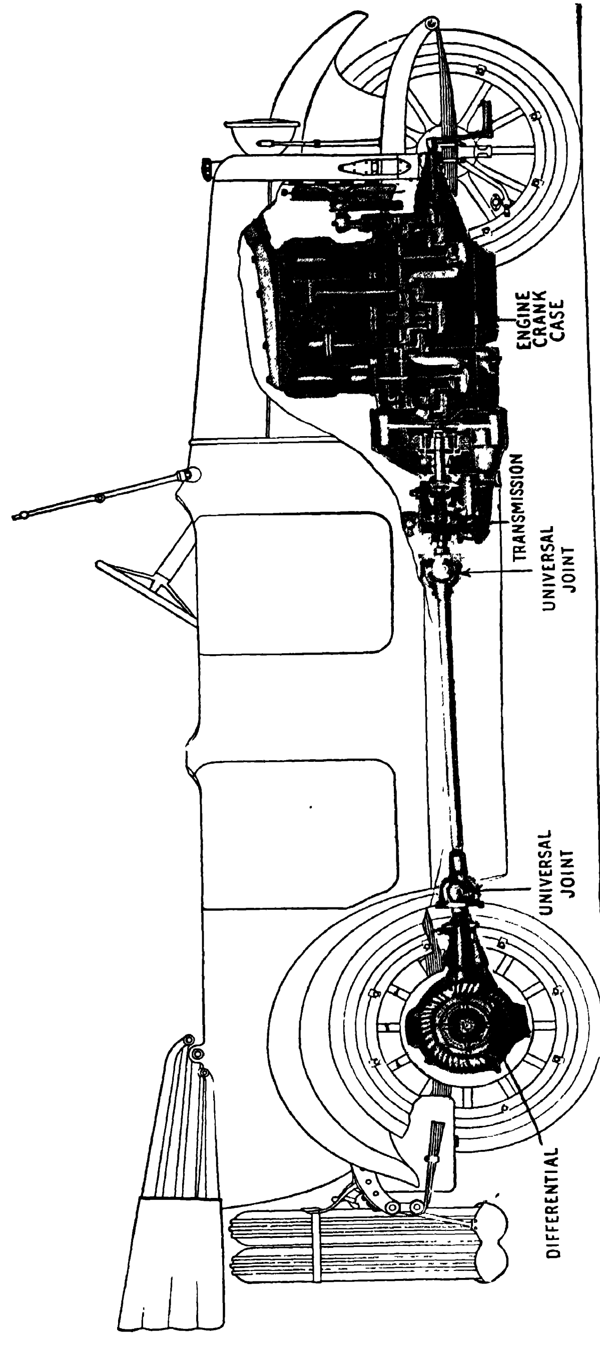


FIG. 95.—Passenger Car in Section, Showing Where Oil is Used. (Veedol.)

free flow of oil through the piping system. The oil should not show too low a flash or fire test, as it will burn off the walls of the cylinders too rapidly, the consumption of oil will be high, and lubrication of the pistons and cylinders will be inadequate. Oil having an exceedingly high flash and fire test is not desirable, as such an oil accumulates carbon rapidly in the combustion space and shows a tendency to plug up the piping system and strainer.

The oil should be as low as possible in carbon residue when distilled slowly to destruction in a retort. This quality insures its burning away from the cylinders and leaving no carbon behind. The chill point should be as low as possible.

Greases.—Greases are used in places where oil cannot be retained easily or where less lubrication is required because the parts move slowly. These include spring shackle bolts, universal joints, wheel bearings, steering mechanisms, rear axles, and certain external points on the engine.

The grease to be used should be carefully selected. There are so many brands and grades on the market, some good and some bad, that it is better to trust to the judgment of the manufacturer.

In all types of transmissions where the seams and oil joints around the shafts are tight at points of exit from the case, transmission oils are to be recommended, (1) because of their excellent lubricating properties, and (2) because of the low fluid resistance which they offer to the rotation of gears and to other parts. Transmission oils consist of residual cylinder stocks, asphaltic oils, and blends of cylinder stock with a small percentage of acidless fatty oils.

Solid Lubricants.—So-called non-lubricating bearings are being used at certain points in later cars. Where the parts are not run constantly —for instance, in starting motors or in clutch operation—oil-less bearings may be installed. These are provided with a solid lubricant of graphite in composition and under ordinary conditions require no attention.

Efficient Lubrication.—A careful observance of the following suggestions will reduce the number of operating troubles:

1. Probably one-half or three-fourths of all engine troubles are due to poor lubrication.
2. Lubricating oil wears out, and the engine systems should be drained and flushed with clean oil every 500 miles.
3. For efficiency and economy, use the heaviest oil permissible in the engine system.
4. Keep sand, dirt, and other foreign substances out of the oiling system.
5. Buy oil in original packages whenever possible.
6. Leaks around the piston will let raw gasoline seep into the crank case and destroy the lubricating quality of the oil.

7. Avoid the use of a grease which is not semi-fluid in the transmission or differential.
8. Do not drive the engine at high speed while the bearings are tight. Over-lubricate rather than under-lubricate while the bearings are stiff.
9. When the crank case has an over-supply of oil the exhaust will show a blue-white smoke.
10. Consult your lubrication chart until lubrication becomes automatic.

Questions.

1. What causes cylinder oil to turn black?
2. What causes carbon deposits?
3. From what source do we get our lubricating oils for gas engines?
4. Why does the oil-pressure indicator show a higher pressure after the crank case has been filled with fresh oil than after it has run a short while?
5. Where are hard greases used?
6. Where should fluid greases be used?
7. What injury will result from gasoline in the crank case?
8. How should the oiling system be cleaned?
9. What are the bases of greases?
10. What solids are used for lubricants?

CHAPTER X

ELECTRICITY APPLIED TO AUTOMOTIVE EQUIPMENT

A KNOWLEDGE of the nature of electricity and magnetism is unnecessary to the repairman or owner so long as everything is working satisfactorily in the electrical equipment. When trouble begins to appear in the ignition, starting, or lighting circuits, it is more easily located and repaired if the operator understands, in an elementary way, how electricity is generated and controlled, and the nature of the magnetic, chemical, and heating effects which may be produced by an electrical current.

While some scientists claim to know what electricity is, the scientific world has not yet accepted their theories as final. However, we do know how to produce electricity, how to measure it, how to transmit it from one place to another, and we know many ways of utilizing it as a form of energy.

Principles of Electricity.—Electricity does not exist in a material sense as does water or coal but must be generated through some form of chemical or mechanical reaction. In its application to the automobile it is chemically generated by dry cells and by storage batteries; it is mechanically generated by magnetos and generators.

When electricity is generated an electrical pressure is created, and if a suitable conductor is provided the charge will flow along the conductor from a point of high pressure to a point of lower pressure. When this charge is flowing along the conductor we have a current of electricity and hence a current of electricity is a moving charge.

If a conductor is passed through a piece of cardboard (Fig. 96) a magnetic field may be shown by scattering iron filings over the cardboard. (When this experiment is attempted with but one conductor a current of 10 or 15 amperes should be used.) This field is called an electromagnetic field to distinguish it from similar fields produced by permanent magnets.

Magnetism.—The property which certain natural lodestones and magnetized pieces of steel exhibit toward other magnetizable substances, of which iron is the best example, is called magnetism. Figures 97 to 100 show magnetic fields which surround permanent magnets. It may be

noticed that the filings arrange themselves in lines which apparently join the two ends of the horseshoe, called poles. These poles are always in pairs, and since they exhibit certain opposing properties one is called positive and the other negative.

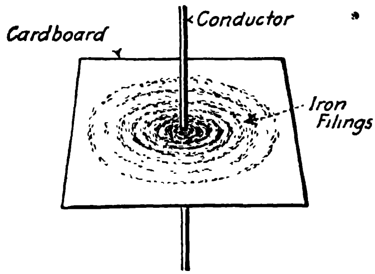


FIG. 96.—A Magnetic Field Produced by a Current of Electricity.

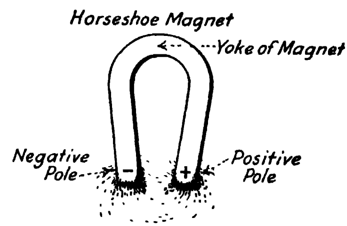


FIG. 97.—Permanent Magnetic Field.

Magnets.—Permanent magnets are always made of highly tempered steel. Soft iron will not retain the magnetism. (For the method of charging magnets see Job No. 7, Chapter III.)

Magnetic fields vary in intensity, depending upon the strength of the magnet. In magnetos large magnets are used and a good, strong field results. (Fig. 98.)

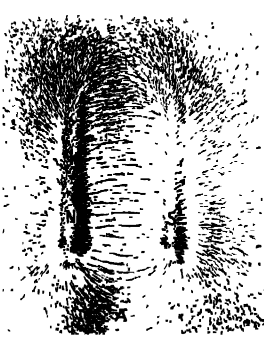


FIG. 98.—Magnetic Field About a "U" Magnet (used on magneto).

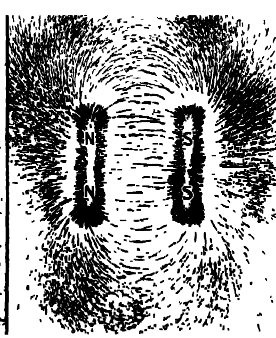


FIG. 99.—Magnetic Field Across Ends of Magneto Magnets.

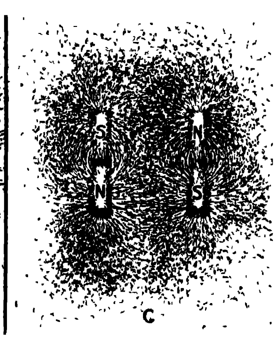


FIG. 100.—"Like Poles Repel, Unlike Poles Attract."

Positive poles always attract negative poles and repel positive. In other words, in two magnetic fields the like poles repel each other and the unlike poles attract. (Fig. 100.) This law is invariably true.

Since the earth is a large magnet with its poles near the north and south geographical poles a magnet suspended in the air will, if it is free to move, arrange itself so that its north or positive pole is attracted toward the north and its negative pole toward the south. The positive pole may be determined in any magnet by suspending the magnet with a thread attached between the two poles. The pole which finally comes to rest toward the north is called the positive, or north-seeking pole, and the other end the negative or south-seeking pole.

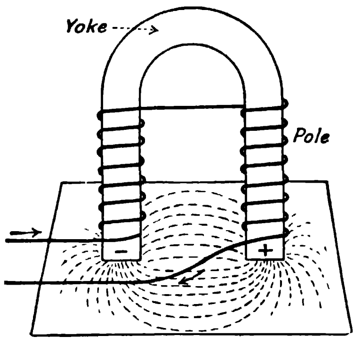


FIG. 101.—An Electromagnetic Field.

Electromagnets are used in bells, motors, generators, relays, cutouts, and a number of other electrical appliances. Figures 101 and 102 show the method of making an electromagnet and its application to an electric doorbell.

A magnetic field is made up of a large number of "lines of force." Each of these lines forms a complete loop or magnetic circuit. (See Fig. 103.) The total number of lines which go to make up the field is called the *magnetic flux*. The term magnetic flux refers to the strength of the magnetic field in lines of force.

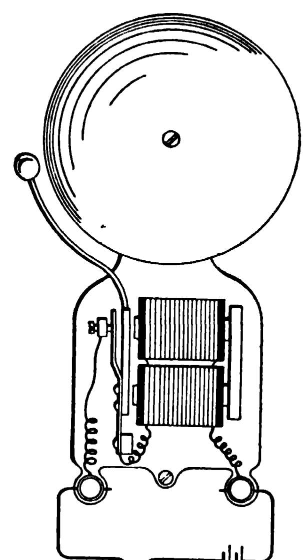


FIG. 102.—Application of Electromagnet in Doorbell.

To appreciate and understand the foregoing statements, a few simple electrical experiments should be performed. The apparatus consists of several flat permanent magnets such as may be made by pieces of files or hack-saw blades, or may be taken from broken telephone receivers. If the pieces are not already magnetized they should be brought into contact with a permanent magnet. Figures 103, 104 and 105 show how the magnets may be placed on a table and covered with a piece of paper. Now scatter a few fine iron filings over the paper and tap it gently with a pencil, observing the way the filings arrange themselves in lines and loops. Change the ends and repeat. If one of the magnets is suspended in the air by a thread tied to the middle so that it is free to swing

in any direction, it will arrange itself in a northerly and southerly direction. Mark the north end with + or *P*, either of which stand for the positive pole, and the other end then becomes the − or negative. Repeat this experiment with magneto magnets and place them on the table as shown in Figs. 98, 99 and 100.

Many interesting experiments can be performed with simple apparatus of this kind. Needles coated with paraffin or heavy oil will float

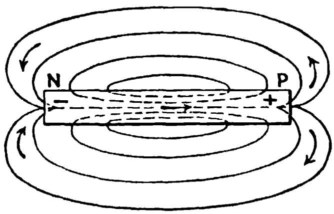


FIG. 103.—Magnetic Circuit.

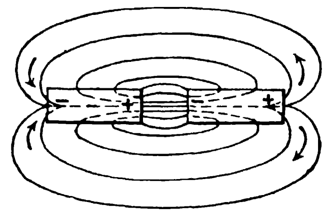


FIG. 104.—"Unlike Poles Attract."

on water. If a needle is rubbed on a pole of a magnet and then placed in water it becomes a compass, one end of which will point in a northerly and the other in a southerly direction.

The lines of force about the needle try to arrange themselves parallel to the lines of force of the earth's magnetic field.

Electromagnets.—As previously stated, whenever a current of electricity flows through a conductor there will be found a magnetic current

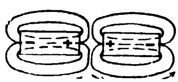


FIG. 105.—"Like Poles Repel."

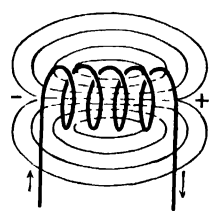


FIG. 106.—Electromagnetic Field.

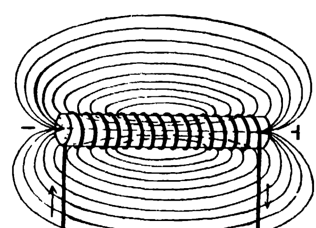


FIG. 107.—Electromagnetic Field with Iron Core.

or " whirl " surrounding the conductor. (Fig. 96.) If the conducting wire through which the current flows is wound on a spool or made into a coil (Fig. 106) the magnetic field is strengthened, and if a soft iron core (Fig. 107) is inserted in the coil the field is intensified.

Magnetos depend upon a magnetic field produced by strong permanent magnets, while starting motors and generators use electromagnetic fields. The strength of the field depends also upon the number

of turns of wire in the coil and upon the strength of the current flowing through the wire.

Telephone receivers, door bells, motors, generators, lifting magnets, spark coils, and many other electrical appliances are built around this principle of electricity.

Conductors and Insulators.—Some substances, such as *metals, salts,* and *solutions*, living plants, and water are good *conductors*, while other substances, as glass, rubber, and mica are called *insulators*. For ordinary purposes copper or iron wire is used for conductors, and mica, rubber, hard fibers, glass, porcelain, and wood are used for insulators.

Effects of an Electric Current.—Four main effects—(1) magnetic, (2) thermal (heating), (3) chemical, and (4) physiological—may be produced by an electric current flowing through a conductor. The magnetic effect sets up the magnetic fields described on the previous pages, and is of very great use in automotive equipment. The thermal or heating effect causes the wires in the armature or field to become warm or hot. In certain carburetors an electrical warming device is placed near the float chamber. This is a coil of resistance wire insulated from the metal parts and through which an electrical current flows.

Various other warming appliances are used, such as electric gloves and cigar lighters. The electric lights illustrate the heating effect, which causes certain kinds of conductors to become so hot that they give off light. The chemical effect of an electric current is illustrated in the storage battery and in electroplating, where a current passed through a solution as a conductor causes certain chemical changes to take place. The physiological effect is illustrated by the shock or sensation produced by inserting a part of the human body in the circuit. Where the pressure is great enough to cause a current of any considerable amount to pass through the human body, the resulting shock is often fatal.

Generating Electricity.—For the automobile, electricity is generated either by chemical action as in a battery, or by mechanical action as with a magneto or generator. Electricity is not produced or generated without the expenditure of some other form of energy. Either a chemical action must take place in which certain forms of latent energy are transformed by chemical action into electrical energy, or a mechanical effort on a suitable machine must be used to transform mechanical energy into electrical energy.

Units of Measurement.—Electrical units of measurements are necessary in the design of electrical apparatus and in the distribution of electricity. Four principal units are used: (1) the volt, (2) the ohm, (3) the ampere, and (4) the watt. The coulomb, while an important unit, is seldom used in practical work.

The Volt.—Whenever electricity is generated an electrical pressure is set up. This pressure, like water pressure (Fig. 108), tends to cause a current to flow through whatever conductor may be provided. A unit called a volt is used to measure this pressure in the case of electricity. It may be compared to pounds of water pressure in a water system.

The Ohm.—No conductor offers an unrestricted flow to an electrical current. While certain metals, such as copper, offer less resistance than others, they all present a certain amount of resistance to an electrical current which increases until, in the case of so-called insulators, practically no current at all can be made to flow through the substance. The resistance which any substance offers to a current is measured in ohms.

The ohm is equal to the resistance offered by a piece of No. 30 copper wire 9.3 feet long. The resistance of a conductor increases with the length of the wire and is inversely proportional to the area of its cross-section. This means that *the longer the wire the greater the resistance, and the smaller the wire the greater the resistance.*

The Coulomb is a unit of electrical-current quantity, such as a quart or a gallon of water.

The Ampere measures the current strength when it flows with a quantity of one coulomb along a wire in a second of time. There is no similar unit in hydraulics which measures the current strength of water flowing in a pipe except as we may say that water flows at a rate of so many gallons per second.

The Watt is the unit of electrical power and corresponds to the horsepower. The equivalent of 1 horsepower is 746 watts. A watt is the power given by a current of 1 ampere flowing under a pressure of 1 volt.

Ohm's Law.—The ampere, volt, and ohm are so related to each other that

$$\text{Amperes} = \frac{\text{Volts}}{\text{Ohms}}.$$

In practice the number of amperes is denoted by I (some authorities use the letter C instead of I for current strength), the number of volts by E, and the number of ohms by R. Using these letters, Ohm's law then becomes (1) $I = \frac{E}{R}$ or (2) $I \times R = E$, also (3) $R = \frac{E}{I}$. These equations are all very simple and by their use most of the problems in electricity may be solved.

For example, if a generator has a charging pressure of 12 volts and the circuit offers a resistance of 3 ohms to the flow of the current, the number of amperes flowing through the circuit may be found.

For $I=\frac{E}{R}$. Eq. (1).

Then $I=\frac{12}{3}$ substituting values of E and R.

Hence $I=4$ amperes.

Again, if we have a 6-volt battery with the head lights on in the lighting circuit, and know that they use 8 amperes, as shown by the ammeter on the dash, we are able to find the resistance in the circuit.

For $R=\frac{E}{I}$. Eq. (3).

Then $R=\frac{6}{8}$ substituting values of E and I.

Hence $R=\frac{3}{4}$ of an ohm.

The watt $=I\times E$ (units of power).

The kilowatt $=1000$ watts.

If the starting motor uses 60 amperes from a 6-volt battery, the power as given in watts $=I\times E$

$$=60\times 6$$

$$=360 \text{ watts.}$$

Since 746 watts are equivalent to 1 H.P. the motor would be giving $\frac{360}{746}$ or nearly one-half of a H.P. The above calculations are all so simple that any one, even though he may not have had more than an elementary education, can easily use the formulæ.

Resistance.—All conductors through which a current flows offer some resistance to its flow. This resistance is peculiar to the substance of which the conductor is made and depends upon the size and length of the conductor. Copper wire offers the least resistance of common metals, while German silver, manganin, and some composition metals offer many times more resistance to the current flow. The creation of an electrical pressure is necessary in order to overcome this resistance when forcing a current to flow along the conductor.

The resistance varies directly with the length of the conductor; that is, a wire 2 feet long has twice as much resistance as a wire 1 foot long. The resistance also varies inversely as the area of the cross-section of the conductor. By this we mean that a wire 1 foot long with an area on the end, or cross-section, of 1 square inch would offer one-half as

much resistance to the flow of a current as a conductor of the same material and same length which has a cross-section of one-half a square inch.

It is easy to understand this principle when we think of a water pipe through which we are trying to force 10 gallons of water per second. If there are two pipes, one 2 inches in diameter and the other 1 inch in diameter, it is evident that it will require more pressure to cause the same quantity of water to flow at the same rate through the smaller pipe, and, other things being equal, the resistance to the flow will be in the inverse ratio of the cross-sections or areas of the pipes.

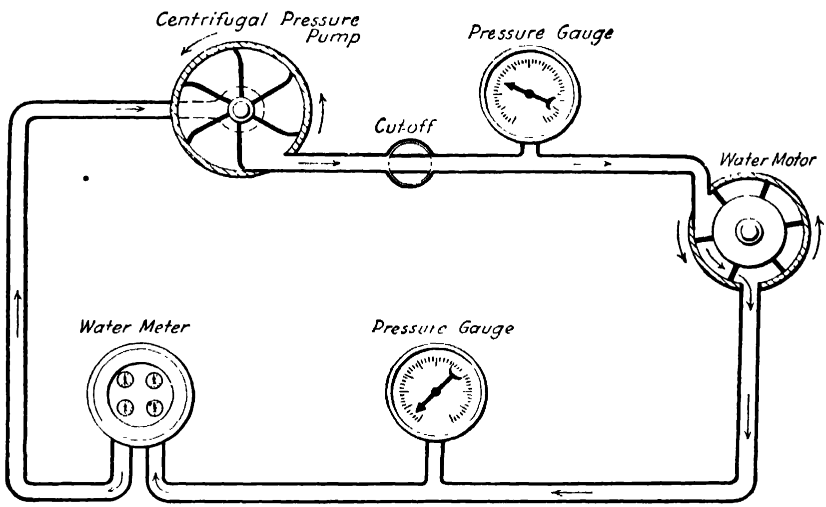


FIG. 108.—Water-circuit Analogy.

Electrical Measuring Instruments.—Since $I=\frac{E}{R}$, only two meters are needed as instruments of measurement in order to determine all three values, for if any two of these quantities are known the third may be found from the formula.

The *ammeter* is a device for measuring the rate of current flow in the circuit. (See Fig. 109.) On the automobile the purpose of an ammeter is to determine at what rate the electricity is flowing from the electric generator into the battery or how fast it is flowing from the battery to the lamps. In the first case it indicates at what rate the battery is being charged, and in the second case how fast the battery is being discharged. To determine whether the generator is working properly, turn off all lights and observe the ammeter. It should indicate the generator starting to charge at about 8 or 10 miles per hour. Now speed

up the car and see that it does not indicate over 12 or 15 amperes at any time. This test will always give warning if the generator is not charging or if it is delivering too little current to the battery and the necessary repairs or adjustments may then be made before it is necessary to remove the battery and recharge it.

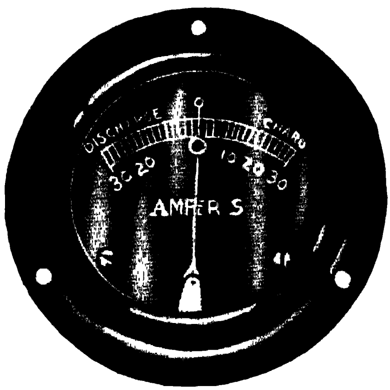


Fig. 109.—Direct-current Ammeter.

Figure 110 shows a voltmeter, which is used to measure the electrical pressure. Both ammeters and voltmeters are made of variable capacities and are calibrated to suit the degree of accuracy required.

Figure 111 shows a volt-ammeter, which has a double scale, one for reading volts and the other for amperes.

Voltmeters are always connected across the terminals between which the voltage or difference in pressure is to be determined. (See Fig. 108, p. 431.) Ammeters are always connected in the circuit through which the rate of current flow is to be measured.

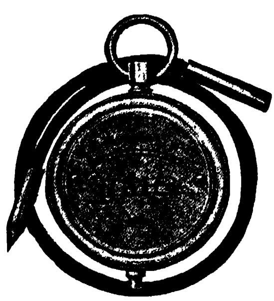


Fig. 110.—Direct-current Voltmeter.

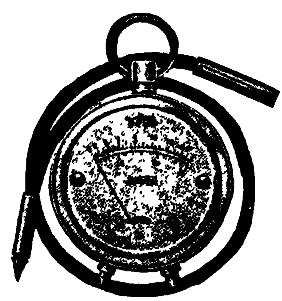


Fig. 111.—Direct-current Volt-ammeter.

Electrical Circuits.—An electrical circuit must always be a closed circuit; that is, the current leaving the battery or generator must have a continuous path through which it may flow back to the negative terminal. Switches are merely mechanical devices for opening and closing the circuit.

In Fig. 112, page 433, is shown a simple circuit with a resistance in series. If there is no resistance in the circuit the battery will

quickly discharge itself. Figure 113 shows a circuit with a starting motor in series. Here the motor part of the circuit offers the resistance. The wires are large because a large current is required to operate a low-voltage motor. Figure 114 shows a circuit with two resistances in parallel. The current divides, part going one way and part the other. If the two resistances are of equal value the current will be equally divided. If one resistance is greater than the other, the larger current will flow through the conductor having less resistance.

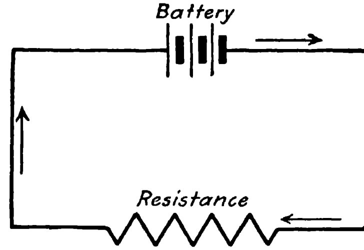


FIG. 112.—Simple Electrical Circuit.

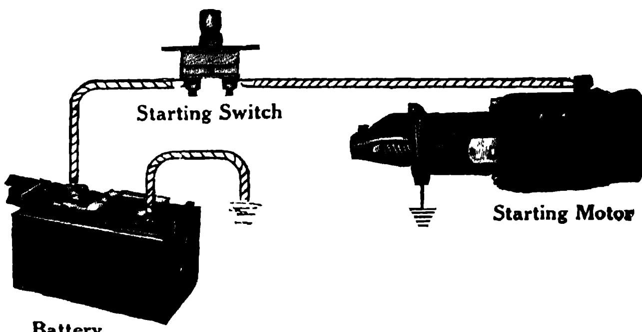


FIG. 113.—Circuit with Motor in Series.

Where a circuit is divided in parallel as in Fig. 114, the total resistance from A to B is less than the resistance through either one of the branches. In fact where R represents the total resistance from A to B and R^1 and R^2 the two resistances in the divided circuit for each branch respectively, $R = \frac{1}{R^1} + \frac{1}{R^2}$.

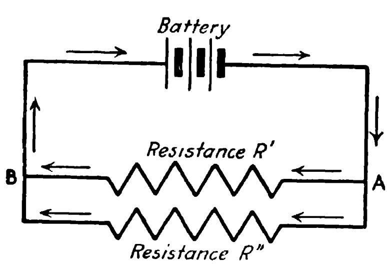


FIG. 114.—A Circuit with Two Resistances in Parallel.

Figure 108, page 431, illustrates the analogy between a water system and an electrical circuit. The pump corresponds to the battery or generator, the cut-off switch to the resistance, the pressure gauge to a voltmeter, the water motor to an electrical horn, motor, or bell. The water meter, while it does not measure the rate of flow as in the case of an

ammeter, is similar in that all the water must flow through it in order to be metered.

When a current of water is flowing it passes through each part of the complete circuit and back to the pump as in the case of an electrical current. No current will flow through this circuit except when a pressure is created by the pump.

Figure 115, page 435, shows the electrical equipment of an automobile. Here there are both series and parallel circuits. For example, the horn is in a simple series circuit which includes the battery, horn, and switch. On the other hand, the head lights are in parallel with each other since a current flowing past *A* will divide, part of it going to one lamp and part to the other lamp, uniting again at *B*.

"Short Circuits."—Whenever two wires in a circuit come into contact, as might happen at *C* in Fig. 115, page 435, the current will cut across and short-circuit its path. This would practically eliminate the current through the head lights and might result in a run-down battery. "Short circuits" occur because of poor insulation, loose wires, water on the wires, or carelessness in handling tools. When working on the electrical equipment the repairman should be very careful to avoid damaging either the battery or the generator in this way.

Batteries.—A battery is a chemical pump which under certain conditions produces an electrical pressure. There are many different kinds of batteries. They are all classified under wet types, dry types, and storage batteries. Of these three, automobile work is concerned only with the dry and storage types.

So-called dry cells are not actually dry inside but have a solution absorbed in a composition of manganese dioxide, plaster of Paris, and other substances. If this mixture becomes dry the cell loses its value. The advantage of the dry cell lies in the fact that it will not spill when lying in any position. The elements are made of zinc and carbon. The dry-cell battery is now seldom used on automobiles except for emergencies. The best dry cells have a maximum pressure of about 1.3 volts each. When in use, owing to the high internal resistance, 6 dry cells are required to take the place of a 6-volt storage battery. (See Fig. 118, p. 436.)

The cells are connected in series and when necessary their strength should be tested for a discharge rate by a testing ammeter. It is not worth while to test dry cells with a voltmeter. The pressure or volts may be up to an approximate standard of 1.3 and the capacity nearly exhausted.

Figure 119, page 436, shows a 3-cell (2.2 volt per cell) lead storage battery connected in circuit with four 6-volt lamps. These lamps must

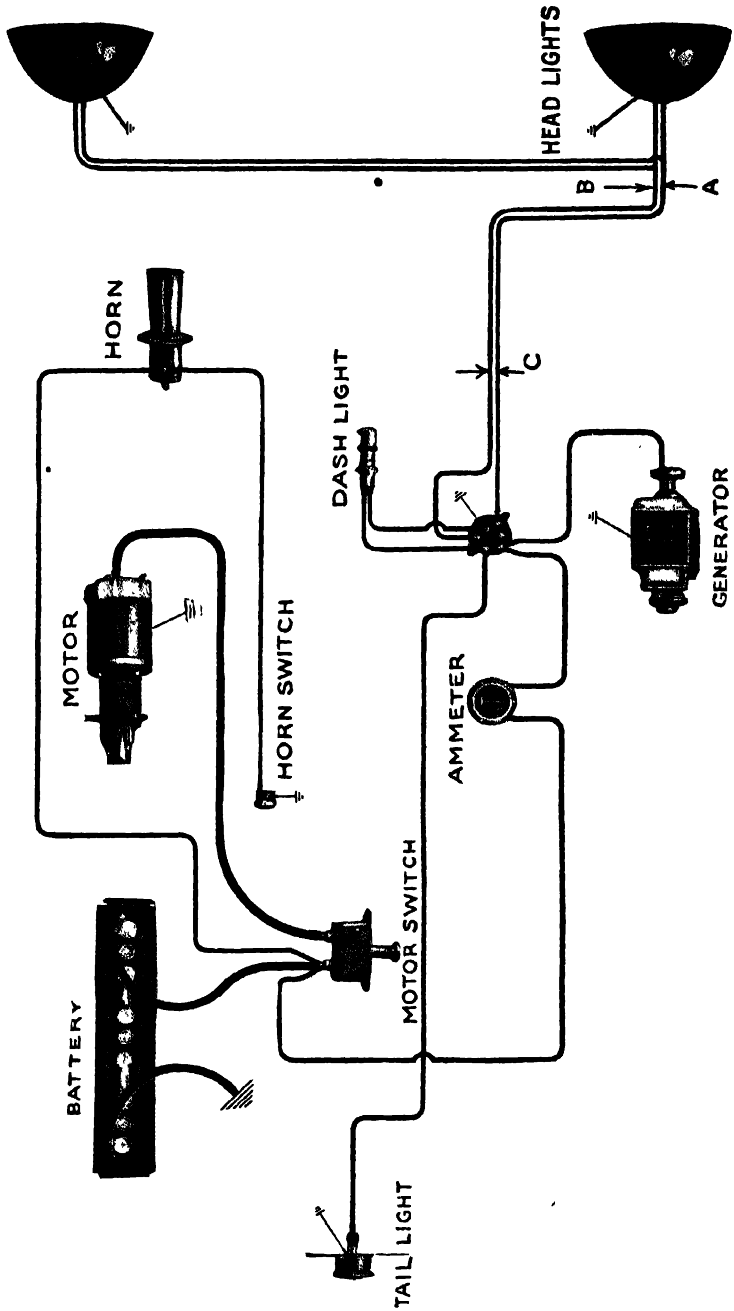


FIG. 115.—Wiring Diagram, Showing Both Series and Parallel Circuits.

be connected in parallel since their total combined resistance, if connected in series, would reduce the current too low to light up the filament. This set is called a 6-volt battery and is used on many automobiles.

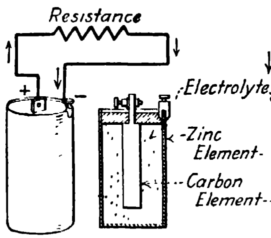


FIG. 116.—Dry Cell with Cross-section.

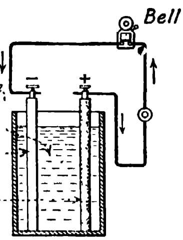


FIG. 117—Wet Cell with Zinc and Carbon Elements and a Sulphuric Acid Solution.

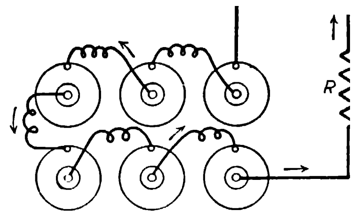


FIG. 118.—Dry Battery: Six Cells Connected in Series.

Lead Storage Battery Construction.—The storage battery is essentially the reservoir in which the excess electrical energy, generated when the car is running, is stored for future use in cranking the motor and operating the lights. In 6-volt systems it is composed of 3 cells or

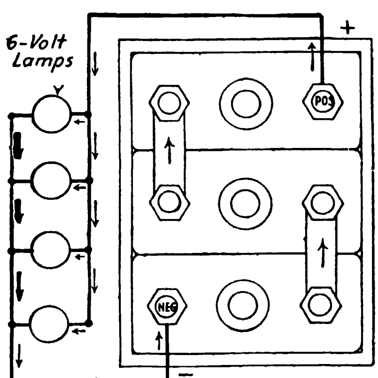


FIG. 119.—A 3-cell, 6-volt Storage Battery in Circuit with Four 6-volt Lamps Connected in Parallel with Each Other.

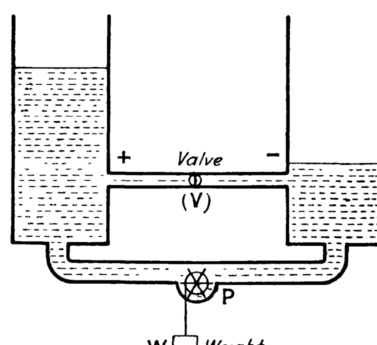


FIG. 120.—Water Analogy to a Battery.

hard rubber jars in which a number of lead plates are immersed in a solution of sulphuric acid and distilled water known as the electrolyte. The plates are stiff lead grids which hold a paste made of various oxides of lead. A group of plates in each cell is joined to the negative ter-

minal, and another group is joined to the positive terminal, thin rubber or wooden "separators" being inserted between the plates to prevent them from touching one another. In the factory forming process the material on the positive plates becomes converted into brown peroxide of lead while that on the negative plates assumes the form of gray, spongy, metallic lead. The material on both plates is known as active material.

The pressure (Fig. 120) is created by the water pump at P which operates under the weight W. When the back-water pressure becomes equal to W the pump stops and maintains this pressure until it is lowered by opening the valve V which corresponds to the exterior circuit on a battery. When the energy stored in W is exhausted the difference in pressure, or E, is zero and no current will flow from + to − as is true in a battery.

Action of a Storage Battery.—When a current is taken from the storage battery for lighting or cranking purposes, the sulphuric acid in the electrolyte combines with the active material of the plates to form sulphate of lead. When the battery is recharged, either by the current from the generator or from an outside source, the lead sulphate is again converted into the original active material and the acid is set free in the solution.

Sulphuric acid does not evaporate, and, unless one of the battery jars should leak, the amount of acid in the cell remains always the same regardless of whether it is combined with the active material in the form of a sulphate or is free in the solution; but, since the acid combines with the active material of the plates to form a sulphate as the battery is discharged, the amount of free acid remaining in the solution at any time indicates accurately the charged or discharged condition of the battery. Any measurement, therefore, of the relative amount of acid in the electrolyte will also be a measurement of the battery's charge.

The Hydrometer.—Sulphuric acid is heavier than water, and in a mixture of acid and water such as the electrolyte of the storage battery, the specific gravity will be proportional to the amount of acid. The hydrometer shown in Fig. 10*a*, page 195, consists of a weighted float with a graduated stem, which when immersed in the liquid will indicate the condition of the electrolyte and of the relative charge.

A fully charged battery will show a gravity reading of 1.280 to 1.300.* If the battery always tests above 1.250 there is no need for worry. If the reading is below 1.250 the gravity should be restored by using the lamps sparingly and by driving at a speed of about 18 or 20 miles per hour.

*Usually written 1280 to 1300, etc.

Job No. 10, Chapter III, describes how to charge and care for storage batteries.

Specific Gravity.—The specific gravity of a substance is the number of times it is heavier than the weight of an equal volume of water. It may be expressed thus:

$$\text{Specific gravity (sp.gr.)} = \frac{\text{Weight of body or substance}}{\text{Weight of an equal volume of water}}.$$

The specific gravities of six common liquids are given below:

Water (distilled)	1
Sulphuric acid (c.p.)	1.841
Muriatic acid	1.2
Alcohol	.792
Gasoline (high test)	.65
Battery solution	1 300 (Read 1300)

Two kinds of hydrometers are in common use: the specific-gravity hydrometer, which is shown in Fig. 10*a*, page 195; and the Baumé hydrometer. This latter is used in various commercial manufacturing plants to give the relative strength of liquids but is not used in storage-battery work.

In making up a solution of sulphuric acid and water, always use distilled water. *Never pour water into pure acid* since so much heat is formed that it is very dangerous. Measure out the approximate amount of water and add the acid slowly, letting the mixture have time to cool. Avoid getting any acid on the body or clothing.

The current from a battery always flows out from the positive or + pole or terminal and returns at the negative or −. When charging a battery this action is reversed, the current from the charging station entering at the positive and leaving at the negative.

A discharged battery is always the result of inadequate charging, a waste of current, or a battery of too small capacity. If the battery soon runs down, after having been fully charged, there is trouble somewhere in the wiring system which should be located and corrected.

Putting acid or electrolyte into the cells to bring up the specific gravity can do no good and may do great harm.

If for any reason an extra charge to the maximum specific gravity is needed, it may be accomplished by running the engine idle or by using a direct current from an outside source.

In charging from an outside source *use direct current (D. C.) only* and limit the current to the proper rate in amperes by connecting a suitable resistance in series with the battery. Incandescent lamps are convenient for this purpose.

Connect the positive battery terminal (painted red or marked *POS* or *P* or +) to the positive charging wire, and the negative terminal to the negative wire. If the terminals are reversed serious injury to the battery may result. Charging wires may be tested for polarity with a voltmeter or by dipping the ends in a glass of water containing a few drops of the electrolyte or salt, as bubbles will form on the negative wire. A large number of small bubbles will leave the negative wire and a small number of larger bubbles will arise from the positive. Do not allow wires to touch each other.

The Edison battery shown in Fig. 122 is not used on gasoline automobiles. It is composed of a series of iron plates with an alkali instead of an acid solution for the electrolyte.

Induction. — The principle of induction plays a very important part in practical electricity. As shown in Fig. 123, page 440, a magnetic field is always set up around a conductor whenever a current is caused to flow through it. This magnetic field increases in strength in proportion to the current and to the number of turns into which the wire is wound, as in Figs. 106 and 107, page 427.

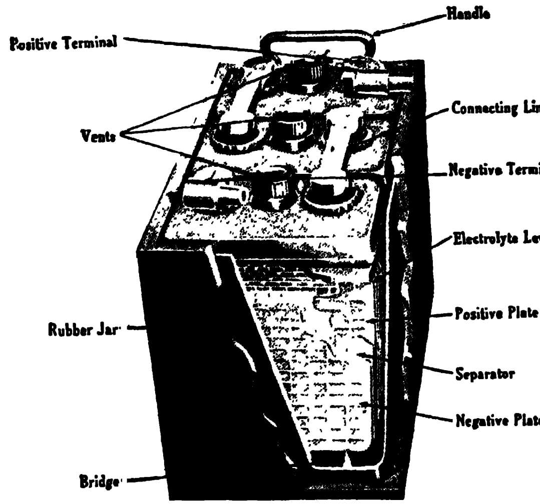


FIG. 121.—Lead Storage Battery.

The introduction of an iron core into the coil increases the intensity of the field many times. This field lasts as long as the current lasts and causes the coil to exhibit the same magnetic properties as are exhibited by a permanent magnet.

In connection with the magnetic field, if a coil of wire or other conductor (Fig. 123) is passed through the field so as to cut the lines of force, an electrical pressure is set up in the wire by *induction* and an induced current will flow through the wire if it is a part of a closed circuit.

The induced current lasts only so long as the wire is in motion or is cutting the lines of force. A magneto has a permanent magnetic field in which the armature coils are located, but no current is generated without motion.

In some magnetos such as the Bosch, the armature coils revolve in the magnetic field; in others, segments called rotors or inductors, as in the Dixie and K.W., revolve and cause the lines of force from the poles of the magnet to change with respect to the wires in a stationary coil. Both of these methods are the same in effect, since the coils of wire cut the lines of force, or the number of lines passing through the coil changes. In either case a current is set up in the primary winding which is proportional to the rate of change. On the Model T Ford the magnets with their magnetic fields revolve adjacent to the coils, and as the number of lines of force cutting these coils change a current is set up in the windings of the coils.

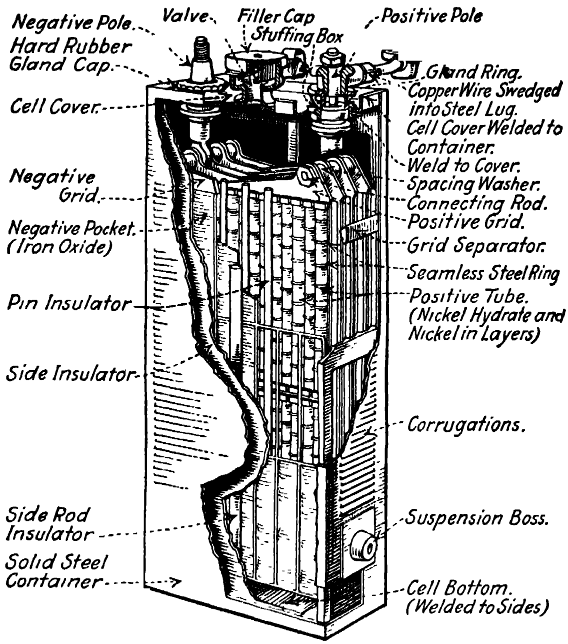


FIG. 122.—Edison Storage Cell.

"Rule o' Thumb."—To determine the direction of the induced current in the wire, place the *right* hand with the thumb extended in the direction in which the conductor is moving (in the figure this is downward), the forefinger pointing in the direction of the lines of force (positive to negative pole); then the second finger if bent at right angles to the thumb and forefinger will point in the direction in which the induced current is flowing.

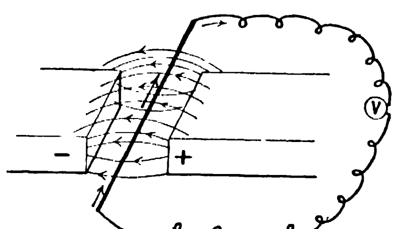


FIG. 123.—Electromagnetic Induction.

The voltage produced in the conductor increases with the strength of the magnetic field, the number of turns in the coil, and the speed

with which it moves. All of these principles are essential to operation of the generator, the motor, the horn, and the other electrical instruments.

Spark Coils.—In Fig. 124 is shown a cross-section of a spark or induction coil. The heavy wire is the primary circuit and a current flowing through it sets up a magnetic field. The secondary or fine wire coils are wound over the primary. If the current in the primary circuit is made and broken, the lines of force are first set up and then taken away. As the lines of force are set up they pass through the outer coils and a current of electricity is induced in these coils. As the lines are taken away by breaking the current, another induced current is formed in the secondary winding but flowing in the opposite direction, so that the making and breaking of the primary circuit induces a pulsating current in the outer or secondary winding. The making and and breaking is caused by an interrupter or vibrator.

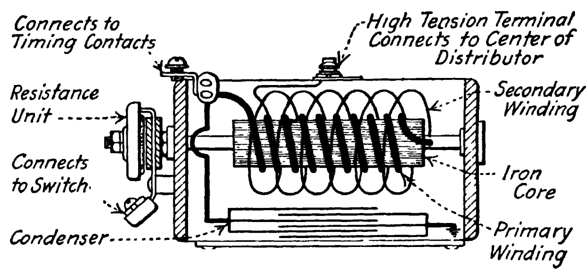


Fig. 124.—Delco Coil and Condenser.

The secondary current has a pressure proportional to the number of turns in the secondary. Hence when a high-pressure or high-tension current is wanted, we construct a coil with a few turns on the primary and many turns on the secondary. The primary and secondary windings are insulated from each other as is also each separate winding of each coil. On the automobile the ignition coil acts as a transformer to change the low-voltage current from the battery or generator to a much higher voltage for ignition purposes.

In the ignition system the current is broken by an interrupter, and the secondary windings are connected to the spark plugs so that at the right instant the interruption of the current in the primary sets up a high-tension current in the secondary which is strong enough to jump across the points of the spark plug. Since one of the effects of an electric current is the production of heat, the current when it jumps the gap,

due to the great resistance of the air, causes an incandescent spark which ignites the mixture.

Condenser.—The condenser (Fig. 124) is made of a number of sheets of tin foil, the alternate layers of which are connected together at each end and carefully insulated from the adjacent layers. *The current does not flow through the condenser.* The condenser is connected across the interrupter, one terminal to each side. The current which is induced in the primary winding, when the circuit is broken at the interrupter, rushes into the condenser. The condenser discharges this current back through the coil in the reverse direction to that in which the current normally flows. This hastens to break down the magnetic field and produces a hotter secondary spark. It also prevents arcing at the points, which is very destructive to them.

When a condenser is subjected to too much pressure the current may puncture the thin sheets of paper separating the leaves of tinfoil and cause a " short." When this happens a new condenser is needed. In practice the condenser serves to increase the voltage of the high-tension current and to keep the interrupter points from burning.

Applications of Electricity to Automotive Equipment.—Electrical equipment to-day includes, in addition to ignition, starting, and lighting, a large number of special appliances for the better operation of the car and for the convenience of the driver and the passengers.

Electric drives have also been demonstrated and may become popular in the future.

The electric horn is well known, as are certain road signaling devices.

One of the newest uses for the electrical current is in supplying a heating device to preheat the gasoline in the carburetor float chamber.

A large number of automatic electric controls, such as cutouts, windshield cleaners, pressure and current regulators, and reverse current cutouts, are now installed.

These devices are too complex in their operation and construction for anyone but a service station mechanic to attempt to replace or repair them; hence a full description of their construction is omitted from this volume. If oil and dirt are not permitted to get into these appliances, little if any attention is required after they leave the factory.

Fuses.—A fuse is supposed to represent the weakest part of a circuit. Whenever the current exceeds the capacity of the fuse it burns out, thus protecting the rest of the circuit. Fuses are easily replaced and are made in different sizes to suit all current capacities. The fuse material is a lead wire encased in a glass or fiber tube to protect adjacent parts from fire due to the burning of the fuse.

Questions.

1. What is meant by magnetism?
2. What different kinds of magnets are used?
3. What is a magnetic field?
4. What are lines of force?
5. How is an electromagnet made?
6. What is a conductor?
7. Why is copper wire so much used in electrical circuits?
8. What is meant by resistance?
9. Explain Ohm's Law.
10. If the pressure of a battery is 12 volts and the resistance of the circuit is 4 ohms, what number of amperes of current strength are flowing through the circuit?
11. What kinds of batteries are suited to the automobile?
12. How is a lead storage battery made?
13. What care should a storage battery receive?
14. How is an ammeter connected in a circuit?
15. What should be used to test a dry cell? A storage battery?
16. What is meant by specific gravity?
17. Explain what is meant by an induced current?
18. How can you tell the direction in which an induced current is flowing?
19. What is a condenser? How is a condenser connected in the ignition circuit?
20. If a magneto were used for lighting, would a condenser be used in the lighting circuit?

CHAPTER XI

IGNITION

Battery Systems.—In the early days practically all cars were operated on batteries in the ignition systems. Many of these were dry batteries. Magnetos were then added as a special equipment and batteries were used only in starting.

With the advent of the self-starting motor the storage battery became an important piece of equipment. A direct-current generator was necessary to keep the battery fully charged, and the magneto again became an unusual part of the equipment. It is still retained for ignition purposes on trucks and tractors.

Battery systems include 6-volt and 12-volt batteries. These vary from 60- to 130-hour capacity, as needed for the electrical equipment installed.

The battery (Fig. 125, p. 445) is connected to the charging circuit in series with a relay cutout which prevents it from discharging back through the generator when the generator is not charging.

The current flows from the battery to the ammeter, to the switch, to the coil, to the interrupter, and then to a ground connection, to return to the negative side of the battery. Some systems complete the generator circuit by means of the ignition switch (Fig. 126). High-tension current is generated in the coil and goes to the proper spark plug for igniting the mixture.

Low-tension Coils.—Low-tension spark coils are used on certain stationary engines where interior " make and break " devices are used. This coil is commonly known as the " kick " coil. It is made of an iron core consisting of a bundle of soft iron wires and a single coil of wire. The coil has a considerable number of turns but not as many as are in a high-tension secondary circuit.

High-tension Coils.—The high-tension coil is used in connection with battery and low-tension magneto ignition systems. Where high-tension magnetos are used the coil is included as a part of the armature winding and serves the same purpose.

The current from the battery does not have sufficient pressure or voltage to jump the gap of the spark plug, and therefore the induction

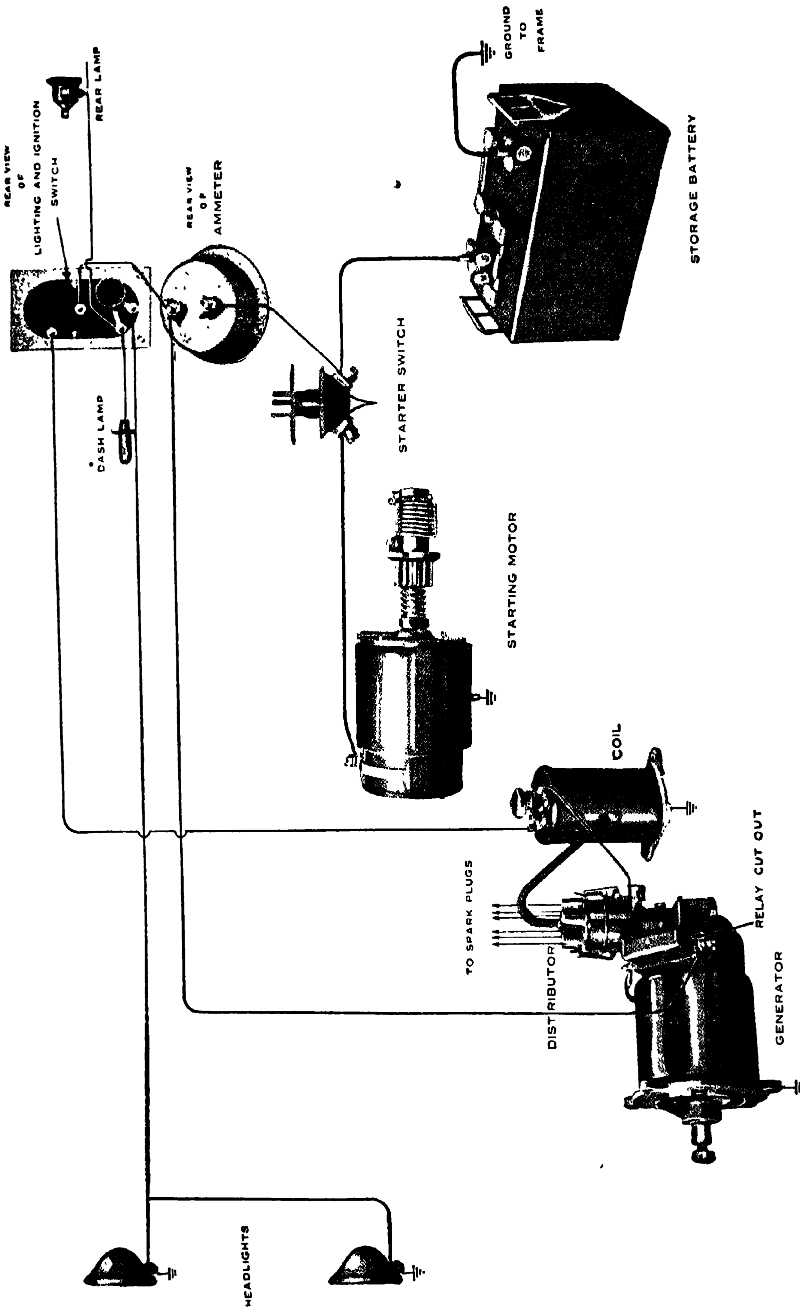


Fig. 125.—Pictorial Wiring Diagram. (Remy.)

coil is provided. It transforms the battery current into a high-tension current. The high-tension current is conducted by a heavily insulated

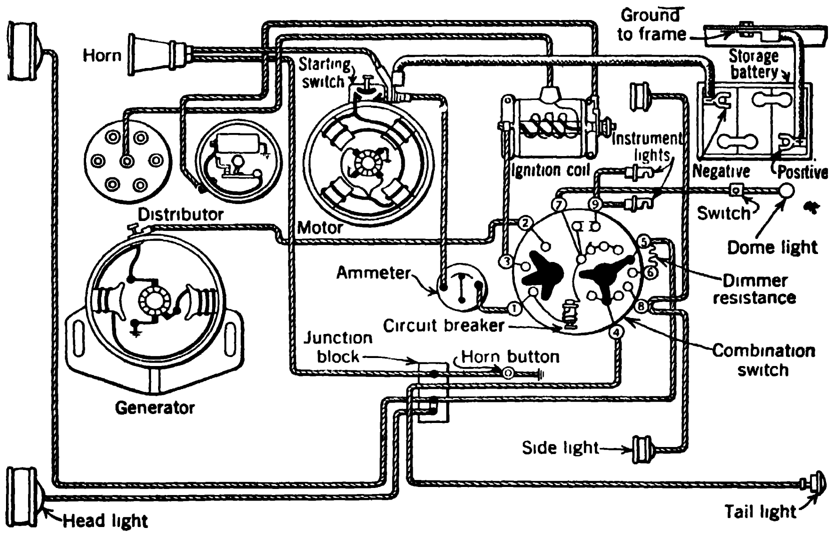


FIG. 126.—Wiring Diagram of Electric System. (Nash.)

wire from the terminal on the side of the coil to the center terminal of the distributor, which then directs the spark to the cylinders in proper order of firing. The return circuit for the high-tension current from the

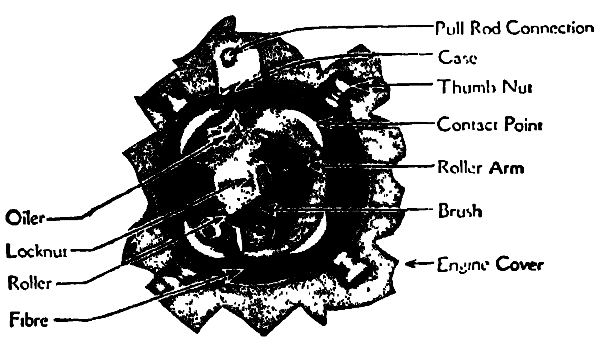


FIG. 127.—The Model T Ford Commutator or Timer.

spark plug is through the engine and metal parts of the car back to the metal bases of the coil.

Vibrators.—On some types of cars a coil vibrator is used to interrupt the current flowing through the primary winding. The interrup-

tion of the primary current sets up a corresponding high-tension current in the secondary. On the Model T Ford an individual vibrator is located on the top of each coil.

The commutator (or timer) (Fig. 127), determines the instant at which the spark plugs must fire. It affects the " make and break " or vibrator in the primary circuit. The grounded wire in the magneto allows the current to flow through the metal parts to the metal roller in the commutator. Therefore, when the commutator roller in revolving touches the four commutator contact points, to each of which

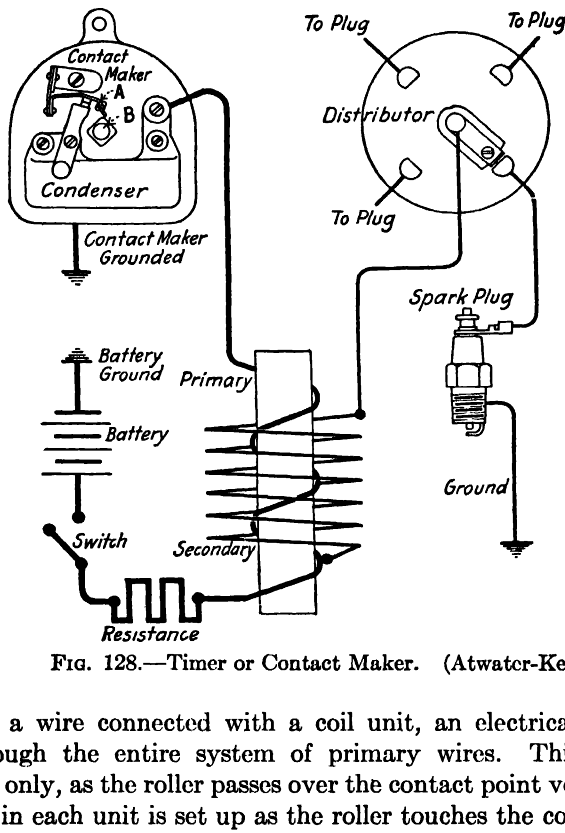


FIG. 128.—Timer or Contact Maker. (Atwater-Kent.)

is attached a wire connected with a coil unit, an electrical circuit is passed through the entire system of primary wires. This circuit is momentary only, as the roller passes over the contact point very rapidly. The circuit in each unit is set up as the roller touches the contact point connected with that unit.

Timers.—Timers are electrical switches which open or close (depending upon whether a closed- or open-circuit type is used) at the right instant for the ignition of the charge in the cylinder. They are also called contact makers, commutators, circuit breakers, and interrupters. Figure 128 shows an Atwater-Kent contact maker for a closed-circuit

system. The opening or closing of the circuit is produced by a cam *B* rotating against the contact arm *A*. Each time the contact points are opened by the cam action a high-tension current is induced in the secondary winding of the coil, and a single hot, heavy spark occurs at a plug. The proper plug is mechanically selected by means of the distributor.

It is evident that the greatest power will be developed if the charge can be exploded at the instant it is under greatest compression. If the charge were ignited the instant that electrical contact is made in the timer, regardless of the engine speed, the spark might be set permanently in one position. Some time is consumed, however, from the instant the circuit is closed in the timer until the spark is given at the spark plug. This elapsed time must be taken into consideration when dealing with such a fast-moving mechanism as a gasoline engine. The

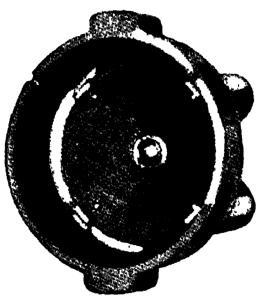


FIG. 129.—Remy Distributor Cover.

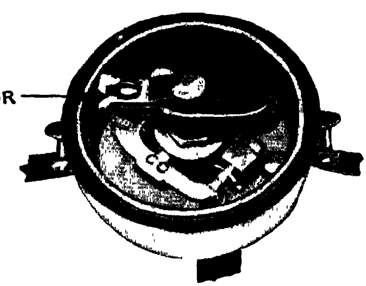


FIG. 130.—Remy Timer.

relative speeds of the burning of the mixture in the cylinder and of the travel of the piston are not equal at all engine speeds. It is evident, therefore, that the spark should be advanced as the engine speed increases and retarded as the speed is decreased.

The spark throttle is used to advance the timer to suit the speed of the engine. Some systems are equipped with automatic controls for this purpose.

Distributors.—The distributor is usually mounted directly over the timer. It distributes the high-tension current to the proper cylinder. The distributor rotor or segment rotates with the timing shaft, and at the instant the high-tension spark is produced it comes either into contact or almost into contact with the high-tension wire terminal leading to the spark plug on the cylinder, which is ready to fire.

Figure 129 shows a Remy ignition distributor which is mounted over the timer circuit-breaker (Fig. 130).

Automatic Spark Controls.—The time at which the spark occurs in the engine cylinder relative to the travel of the piston is controlled by the breaker cam and the breaker contacts. The spark lever is connected with the manual advance lever on the distributor, which advances or retards the position of the fiber block in relation to the breaker cam, and consequently advances or retards the time of the spark in each cylinder. Besides this manual advance, a centrifugal type of automatic advance is usually connected to the shaft, and advances the position of the timing cam in exact relation to the speed of the engine.

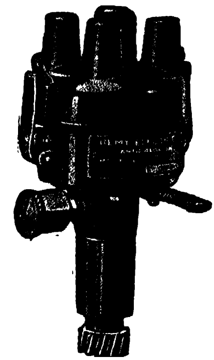


FIG. 131.—Remy Distributor Assembly.

Owing to the fact that the combustion of the mixture under compression is not instantaneous, there is a certain point in the travel of the piston, depending upon the speed of the engine, at which the occurrence of a spark will produce the maximum power. Naturally this position is somewhat ahead of the top of the piston travel and must be advanced still farther as the engine is speeded up. It is the function of

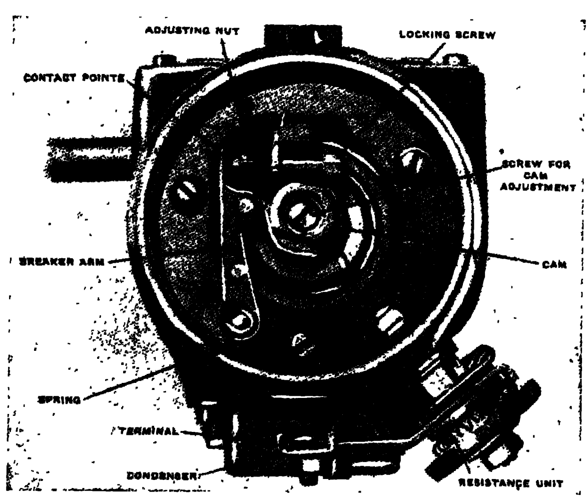


FIG. 132.—Distributor Base, Showing Resistance Unit and Contact Points.

this automatic advance to cause the spark to occur as near as possible to this most efficient position of the piston travel for the different engine speeds. The manual spark control is for the purpose of properly retard-

ing the engine for starting, for making any adjustments to the carburetor, or for idling. When the spark lever is advanced as far as possible without causing the engine to knock and the engine " picks up " rapidly and smoothly, it is in the proper position for ordinary driving. In starting, the spark lever should be retarded.

In the automatic control systems used on some cars, when the lever is in a fully retarded position, the distributor is set to fire so that its spark occurs five degrees late, or about $\frac{5}{8}$ second later than top dead center measured on the flywheel. A variation of $\frac{1}{4}$ second in either direction from this position is allowable. In making this adjustment, manufacturers' instruction books should be consulted for specifications.

Figure 6*a*, page 179, in the chapter on Electrical Work, shows the type of automatic advance used on Delco systems.

Generators.—With the addition of starting equipment on the automobile, a generator becomes necessary to keep the storage battery fully charged. Both two- and four-pole generators are used.

The generator operates on the principle of induction and generates a current only so long as the armature is in motion.

The generator has three essential parts in its operation:

1. A magnetic field.
2. A coil of wire moving in the magnetic field.
3. A mechanical power which turns the coil and provides the mechanical energy to be transformed into electrical energy.

On the automobile the engine supplies the necessary force required to turn the armature. The current on D.C. generators is collected on the brushes. These bear upon the revolving commutator, the segments of which are connected to the ends of the armature coils.

Third Brushes.—Most models use three brushes. The two main brushes collect the current from the armature. The third or regulating brush is used to control the output of the generator for the varying speeds at which the car is driven. This is done by connecting the third brush to one end of the generator field. As the voltage at this brush varies at different speeds, because of its position relative to the main brushes, the field strength varies also, with the result that a practically constant output is obtained for the varying car speeds. The maximum charging rate is obtained at comparatively low car speeds; at high speeds it is reduced.

Upon leaving the factory each generator is adjusted to give an ample charging rate for normal driving conditions. Occasionally, however, cars are operated in such a manner that they require much more or a great deal less current than the average, in which case it is advisable

to change the output of the generator. In order to do this, the third brush is mounted in such a manner that its location on the commutator may be changed either to increase or to decrease the output.

The third brush is accessible when the band covering the brushes is removed. The brush holder is mounted by means of two slot screws. The loosening of these screws permits the third brush to be moved either to the right or to the left, as shown in Fig. 133. Whenever the brush is moved in either direction a piece of fine sandpaper should be drawn between the commutator and the brush, with the sand side toward the brush, in order to fit the brush to the commutator. If this is not done the charging rate will be lowered. The charging rate of the generator should never exceed 15 to 20 amperes, as this is above the capacity of most generators.

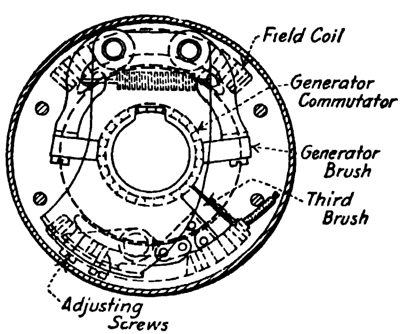


FIG. 133.—Third-brush Adjustment on Delco System.

A general rule for adjusting the third brush is to move it in the direction of rotation of the armature to increase the output and in the opposite direction to decrease it.

Correct charging rates for different generators are furnished in instruction manuals. The generator is designed to charge the battery at the rate which is best adapted to it. It will keep the battery fully charged and will replace the current used for the lights and starter, provided the car is run a reasonable distance at a speed of more than 10 miles per hour in the day time. If the car is driven at night with the lamps burning, the generator current is used as fast as it is made and therefore does not build up the battery. If the car is driven exclusively at night, increase the charging rate or have the battery charged occasionally from an outside source.

Thermostat Control.—Because of the increased use of lights and longer application of the starting motor required to start a stiff, cold engine, the battery is called upon for considerably more current in winter than in summer. Moreover, since the condition of the streets in winter imposes slower driving, the battery does not receive even the normal amount of recharge from the ordinary type of generator, and, as a result, it is necessary on some makes of cars to have the battery charged several times during the winter.

A larger capacity generator could not safely be used without some means of protecting the battery from the overheating which a continuous

high-charging rate would cause, especially in the summer months. Overheating will seriously damage the plates and shorten materially the life of the battery. By reducing the charging current automatically whenever

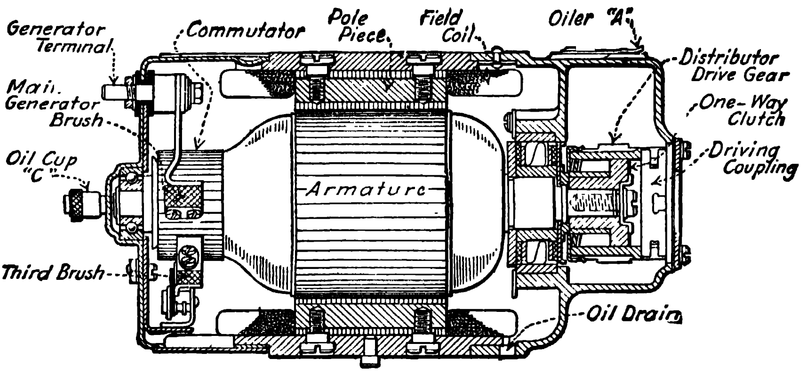


FIG. 134.—Delco Generator.

the battery tends to heat up, the thermostat control (Fig. 15e, page 211) has made possible a generator of larger current capacity for winter use.

The thermostat insures against the overheating of the battery which a continuous high-charging rate would cause, with consequent damage to the plates, especially in summer. It not only insures maximum battery life but also enables the highest charging rate which the battery may safely receive at different temperatures to be used.

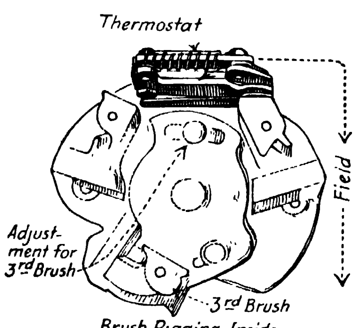


FIG. 135.—Remy Thermostat and Third-brush Rigging.

The thermostat is composed of a resistance unit, two silver contact points, and a spring blade holding one of the contact points. The blade is made of a strip of spring brass welded to a strip of nickel steel—a combination which, owing to the greater expansion of the brass side, warps at its free end when heated. The blade is riveted through insulation washers to the bracket, and the spring tension holds the two contacts together firmly at low temperatures; but as soon as the temperature rises to approximately 175 degrees the blade bends and separates the contacts.

When the thermostat contacts are closed the full field current passes through them and a full-current output from the generator is produced.

After the engine has been run long enough to heat up the battery through a high-charging current, the thermostat automatically inserts the resistance into the field circuit and thus reduces the output.

Reverse Series Field-winding Control.—Another device for controlling the current of the generator is a reversed series field winding which opposes in electrical effect the shunt winding. This effect increases as the speed of the generator causes a greater current to be generated. It is automatic, has no moving parts, and requires no adjustment or attention on the part of the operator or general repairman.

Vibrating Relay Control.—A third type of current control consists of a vibrating relay, the purpose of which is to control the current output by means of an electromagnet opening and closing a vibrating switch. The vibrator cuts into the circuit of the field winding a resistance which reduces the field current. The relay does not operate until the generated current has reached 10 or 15 amperes. It then cuts in and out as may be needed to maintain a safe maximum current.

Voltage Control.—Another means of maintaining current control is through the regulation of the voltage of the generator. In its construction and operation the device is similar to a current control but operates in such a manner as to prevent the electrical pressure exceeding a certain voltage. When the voltage reaches the maximum for which the relay is set, say 7 or 8 volts, the relay inserts added resistance in the field circuit, thus reducing its magnetic strength and the electrical pressure or voltage generated. As the pressure falls below the safe limit for which it is set, the relay reestablishes the normal field.

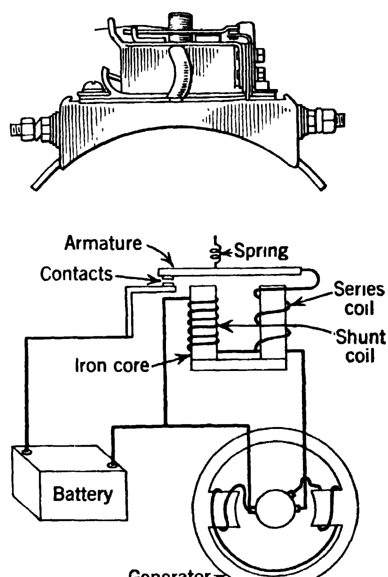


FIG. 136.—Remy Reverse-current Cutout Relay with Internal circuits and Wiring.

Reverse Current Cutout.—The relay cutout (Fig. 136) is an automatic switch for connecting and disconnecting the battery charging circuit. If the battery were left connected to the generator when the engine stops or when the car is driven too slowly for the generator to charge, a reverse current would flow from the battery back through the generator windings and

would soon exhaust the battery. The relay therefore acts as a check-valve, permitting the charging current to flow to the battery when the generator is driven fast enough to produce current, and opening the circuit when the engine slows down or stops. It thus prevents the battery current from flowing through the generator in the opposite direction.

The relay shown in Fig. 136 is composed of two contact points, a movable arm (hinged), a spring, and a simple electromagnet. The spring holds the contacts apart when the engine rests, but when the generator is driven at sufficient speed to develop a voltage greater than battery voltage, the "shunt" coil is energized and pulls down the arm, thus closing the contacts through which the generator current can reach the battery. The charging current must pass through the "series coil" also, which increases the magnetism and insures the arm being held down to a firm contact.

As soon as the engine slows down or stops, the generator no longer energizes the shunt coil; yet the arm would stay down, due to a slight residual magnetism, were it not for the fact that as soon as a current starts to flow from the battery back through the generator and thus reverse through the series coil, the magnet is demagnetized, its poles are reversed, and the contact is released. The reverse current cutout does not regulate the charging rate.

Current Regulators or Circuit-breakers.—An electric current flowing through a conductor tends to heat the metal in the conductor. This effect is proportional to the resistance of the conductor and to the square of the current. If a wire is selected as a conductor for the purpose of carrying a current of a given strength, a larger current will heat the wire and, if excessive, will melt the metal or burn the insulation. To safeguard the electrical equipment, circuit-breakers are used. These circuit breakers act as protective devices, preventing damage to the wiring and equipment by preventing an excessive flow of current in case of grounds or short circuits in the wiring or apparatus. The normal flow of current through the lighting circuits does not in any way affect the circuit-breaker; but in the event of an abnormally heavy current, such as would be caused by a ground in any of the lighting circuits, the circuit-breaker will operate, interrupting the circuit intermittently, causing a vibrating or clicking sound which will continue until the ground is removed. Where automatic circuit-breakers are not used, fuses are set in the circuit to give the same protection. When a fuse is blown it must be replaced, while the automatic device adjusts itself to normal working condition as soon as the trouble is removed. Figures 16*a* and 16*b*, page 214, in Chapter III, illustrate these protective devices.

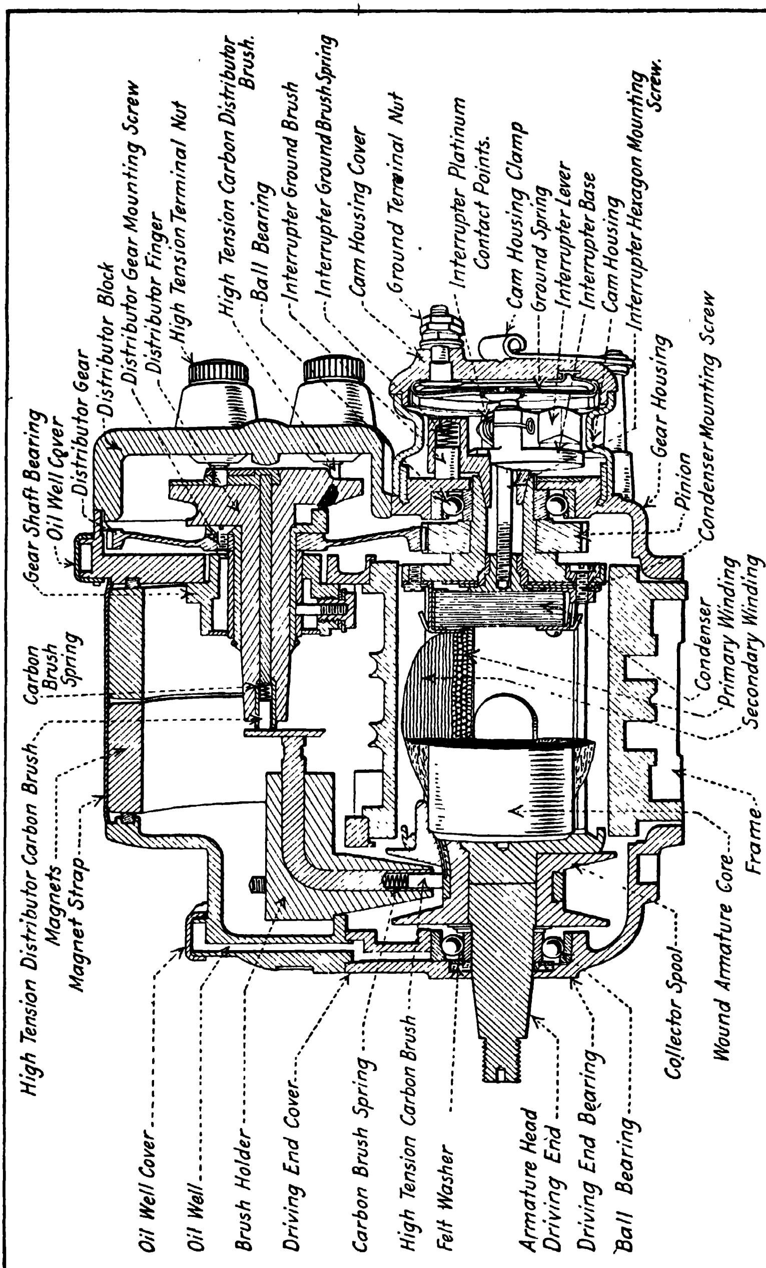


FIG. 137.—Sectional View of High-tension Magneto. (Berling.)

Magneto Ignition.—In so far as the electrical principles are concerned, magnetos are easily understood. As was explained in the chapter on Electricity and illustrated in Fig. 123, page 440, only three conditions are necessary to generate a current by mechanical means:

(1) A magnetic field in which lines of force travel from the positive to the negative pole; (2) a moving coil of wire to cut these lines of force; and (3) a suitable power to move the coil of wire.

In the magneto there are several large permanent magnets to produce the magnetic field and a large number of turns of wire in the armature which in revolving cut the lines of force in the magnetic field.

There are two types of magnetos with respect to the mechanical means taken to cut the lines of force. In Fig. 137, the armature on which the winding is wound revolves in the magnetic field, thus cutting the lines of force. In Fig. 138, there is an entirely different arrangement—the coil *B* is stationary and is wound large in order that the inductor *A* may rotate within it. As the segments of the inductor are offset from each other the lines of force pass through the coil, first in one direction and then in the other; that is, from *C* to *D* for one-half the revolution, and then from *D* to *C* for the remaining half.

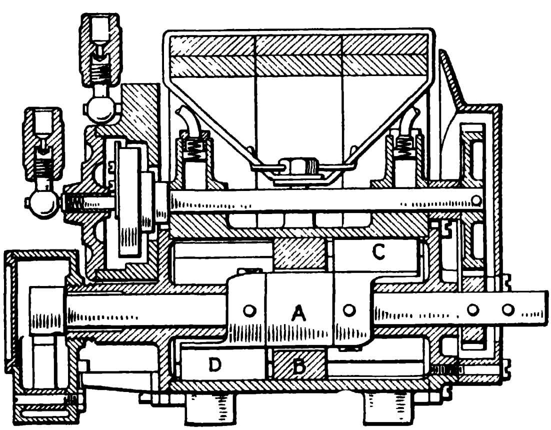


Fig. 138.—Longitudinal Section of Magneto. (Remy.)

The magneto takes the place of a battery in the ignition system. Since the current generated is alternating it cannot be used to charge a storage battery.

Most magnetos include the timer and distributor as a part of the whole unit. High-tension magnetos include also the secondary coil and the condenser.

The Model T Ford magneto (Fig. 7*l*, p. 189) is a part of the flywheel arrangement in which the magnets revolve while the coils are stationary. With this arrangement no brushes are needed. The timer and coils are separate from the magneto. It is a good example of simplicity of construction, as only two parts, the coils and the magnets, are involved.

The principle of induction is common to all types. No current is

generated unless the armature is rotated. The mechanical energy required to turn the armature is then transformed into electrical energy and, after being " stepped up " to the required pressure, is used to ignite the charge.

The types of magnetos and parts are shown in Job No. 7, Chapter III, and specific instructions are given for the operation and repair of this electrical apparatus for such jobs as need not be sent to a service station.

Principle of Operation of Dixie Magneto.—The Dixie magneto contains an additional mechanical feature in that the coil is wound on a movable pole piece which can be shifted about the rotor or inductor so as to advance or retard the field with the spark. The description given on the following pages is typical of the principle of Dixie operation and of the theory of all magnetos.

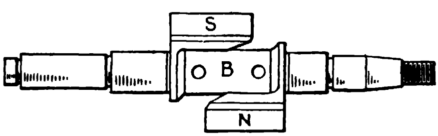


FIG. 139.

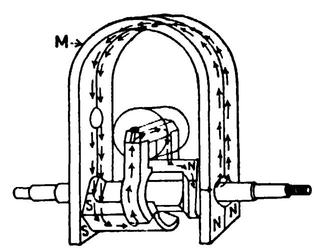


FIG. 140.

FIG. 139.—Rotating Element in Dixie Magneto.
FIG. 140.—Wings N and S of the rotor have Same Polarity as Magnet Poles N and S of the Magnet M.

The Dixie magneto consists principally of a pair of magnets, a rotor, a field structure, a winder, an interrupter, a condenser, and a distributor.

The rotor (Fig. 139), consists of two revolving wings—N and S, separated by a bronze centerpiece B. The ends of the wings are brought into contact with the poles of the magnets as shown in Fig. 140 and therefore bear the same polarity of magnetism as that pole of the magnet with which they are in contact. This polarity is always the same.

The rotor is surrounded by a field structure which carries laminated pole extensions, on which the winding with its laminated core is mounted. As the rotor revolves it causes the flux lines to be twisted about so that the magnetism flows back and forth through the core of the winding, first in one direction and then in the other, according to the position of the rotor in relation to the poles of the field structure.

In a position at right angles to the rotating poles there is a field structure, consisting of the laminated pole pieces 3 and 4, supporting the

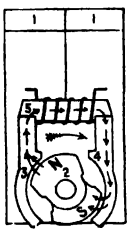


FIG. 141.

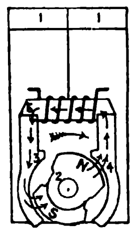


FIG. 142.

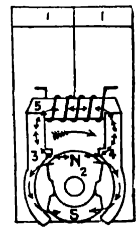


FIG. 143.

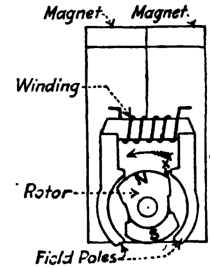


FIG. 144.

FIG. 141.—Flux Flowing in One Direction through Core 5. When the Wing N is Opposite 3 the Flux Flows to 3, and through 5 to 4, back to Wing S of Opposite Polarity.

FIG. 142.—Flux Flowing in Reverse Direction through Core 5. The Pole N has Moved over to 4 and the Direction of the Flow of Flux is Reversed, now flowing from 4 through 5 to 3.

FIG. 143.—Fig. 143 Represents the Rotating Poles Occupying a Midway Position. Here the Field Pieces 3 and 4 are Magnetically Short-Circuited, as it were, thereby Scavenging Stray Lines of Flux of the Core 5.

FIG. 144.—Position of Maximum Current.

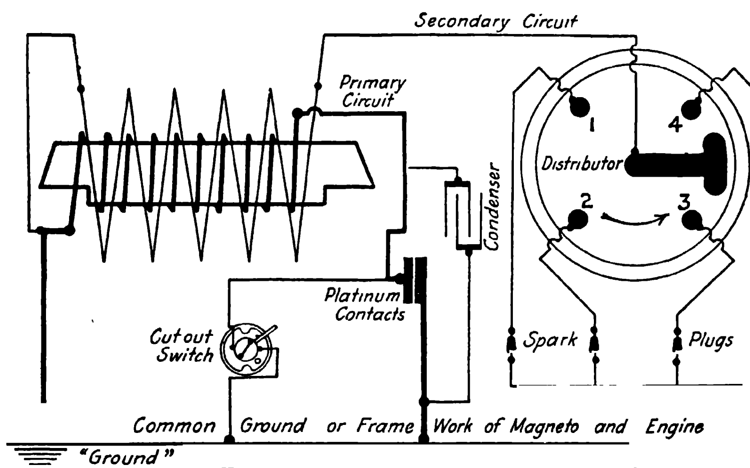


FIG. 145.—Wiring Diagram of Dixie Magneto Circuits.

laminated core 5, carrying the winding. It is obvious that the laminated core of the high-tension winding must reverse its magnetic polar-

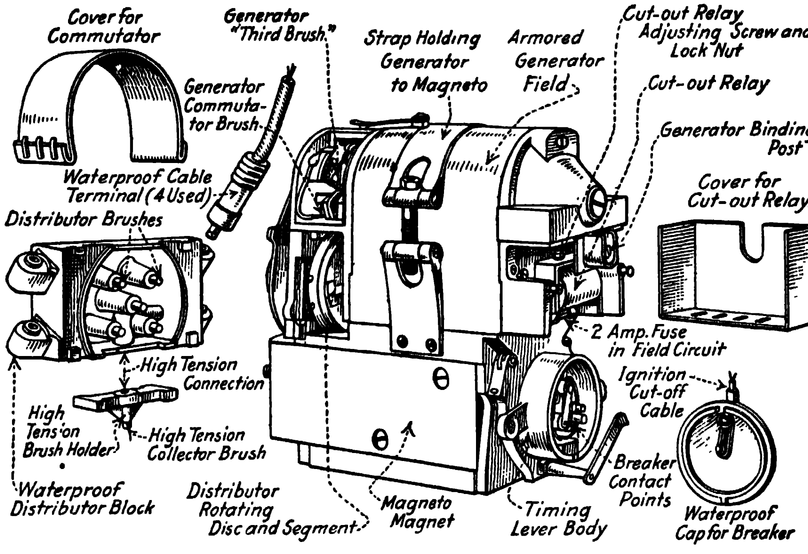


FIG. 146.—Eiseman Magneto.

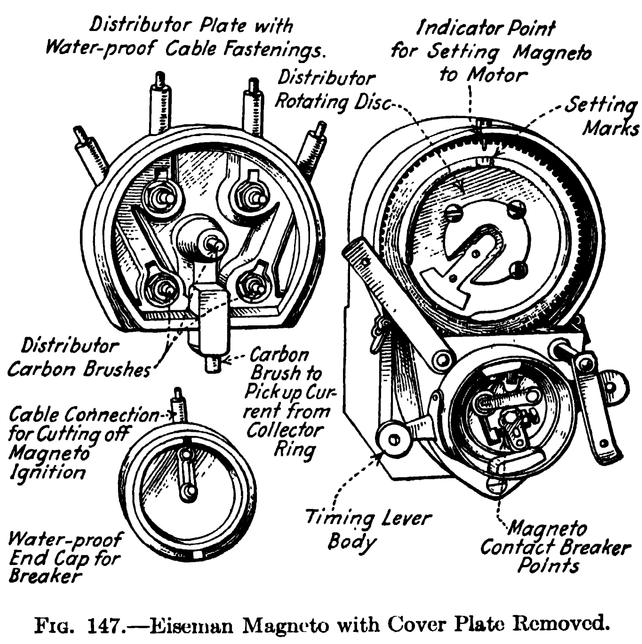


FIG. 147.—Eiseman Magneto with Cover Plate Removed.

ity. It is saturated with magnetism flowing in one direction (Fig. 141). In Fig. 142 the direction is reversed. This reversal must take place at each half-revolution of the shaft. In this type the windings are never in the field. The flux is directed through them as described, producing a hot spark of exceptional igniting power, owing to the quick break and absolute reversal of the flux at each revolution.

The greatest intensity in the primary circuit occurs when the rate of change of the flux through the core is at its maximum. The maximum rate of change of the flux occurs in the position of the rotor shown in Fig. 144, where the rotor wings have just reversed the direction of the flux through the core, the gap between the wing and pole piece being shown at X, in which position the contact points should separate, breaking the primary circuit.

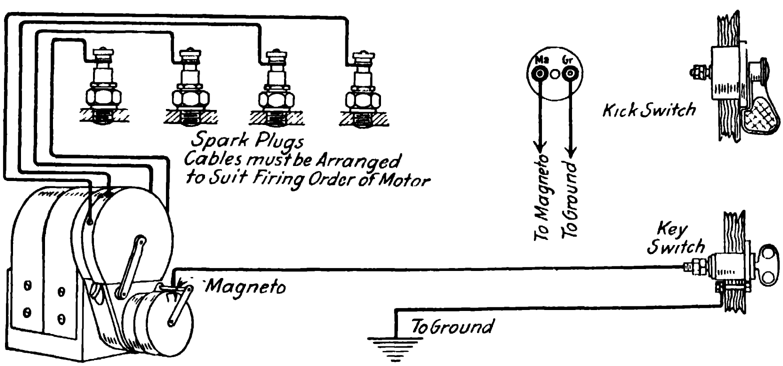


FIG. 148.—Wiring Diagram of Eiseman High-tension Magneto.

Magneto-circuit Diagram.—The primary current (Fig. 145) flows from the ground through the primary winding to the stationary platinum contact, to the movable platinum contact, and to the ground.

The condenser is connected directly across the platinum contacts. The secondary or high-tension current flows from the "ground" through the secondary winding to a rotating distributing member, to the spark plugs, and then to the "ground."

The condensers are located under the yoke and above the coil. They rarely become defective and require little attention except to keep them free from oil and water.

Safety-spark Gap.—On high-tension magnetos a safety-spark gap is provided as a protection for the insulation of the winding and other parts in the secondary circuit. The voltage of the secondary current is made proportional to the resistance which it has to overcome. If the

magneto should be operated without one or more of the distributor wires connected, the safety gap provides a path for the high-tension current. The width of the safety gap should be from $\frac{5}{16}$ inch to $\frac{3}{8}$ inch, depending upon the compression in the engine. Where high compression exists, the safety gap should be set to $\frac{3}{8}$ inch.

Under high compression the sparks may fire across the safety gap instead of firing in the engine. Misfiring under such conditions can be remedied easily by opening the safety gap so that in compression it will offer a greater resistance to the secondary current than the spark-plug gap. Sparks should not be permitted to discharge across the safety gap for any great length of time.

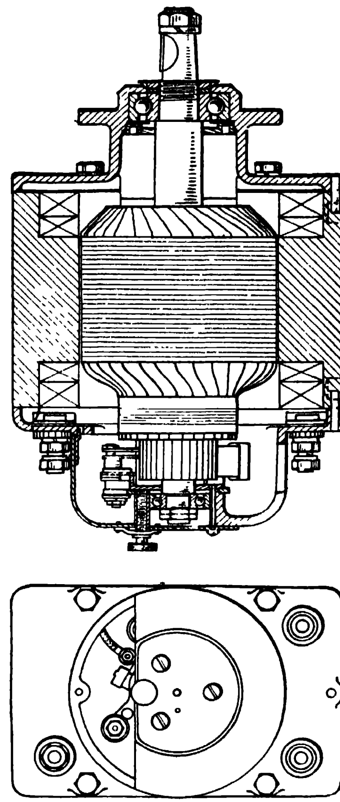


Fig. 149—End View and Cross Section of Motor-generator. (Splitdorf.)

Questions.

1. What is meant by the spark gap?
2. If a spark is not obtained when the engine is cranked, what may be the trouble?
3. What voltages are used in battery systems?
4. What is a low-tension coil?
5. Where are they used?
6. What is a "jump" or "kick" spark coil?
7. What is an interrupter?
8. What device is used on a Model *T* Ford car to interrupt the current?
9. Where are interrupters placed, in the primary or secondary circuits?
10. What is a high-tension coil?
11. How is it constructed?
12. What is a condenser?
13. Where is a condenser connected in the circuit?
14. How should a condenser be tested?
15. What is a "short circuit"?
16. What is a reverse-current cutout?
17. What is a vibrating-type relay?
18. Does it require more power to turn the armature of a generator when the charging circuit is closed than when it is open? Why?
19. What is a thermostat control?

20. Explain the action of a third-brush regulator.
21. How is it adjusted?
22. What devices are used to protect the wiring if the switch is left closed?
23. A generator is said to receive mechanical energy and to transform it into electrical energy. What is meant by this statement?
24. What is meant when we say a motor transforms electrical energy into mechanical energy?

CHAPTER XII

STARTING AND LIGHTING

The electric starter has been proved, by years of satisfactory service, to be the most reliable and efficient starter and the one that requires least attention. For these reasons, it has become the universal type of self-starting systems.

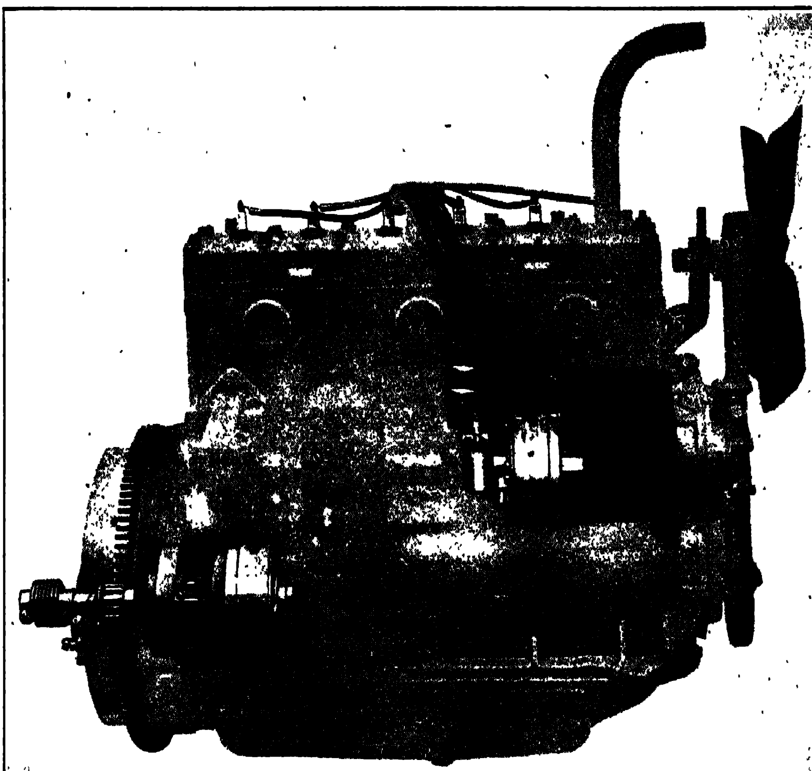


Fig. 150.—Starter, Generator, and Ignition Units—Flywheel Drive, Two-unit Type. (Star.)

The Electric Starter.—The electric starter includes three principal parts: (1) the motor, which is geared to the flywheel or to some other part of the driving mechanism; (2) the storage battery, which is elec-

trically connected to the motor; and (3) the generator, which is electrically connected to the battery and is driven by the engine.

The motor, which is wound in series, is made to operate on a low-voltage current of 6 or 12 volts. With this low voltage a very high number of amperes is required to operate the motor under the load of starting.

The motor contains an armature having a number of coils connected to the segments of a commutator (Fig. 151). The armature rotates between two or four poles on which are field windings. The current from the battery when entering the motor passes through the field and armature coils which are in series with each other. Since the motor must start under a load and develop a powerful pull, it is wound in series.

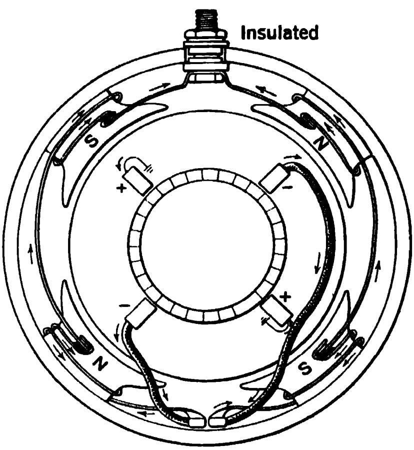


FIG. 151.—Typical Internal Starter Circuit of a Two-unit System. (Autolite.)

With ordinary use the motor will require no care other than to clean the commutator about once each year and to oil as directed by the manufacturer.

Single-unit Systems.—Several makes of cars use a single-unit motor-generator system in which the unit is driven by a chain drive (Fig. 154, p. 467) or where the generator end is connected to the pump shaft by an over-running clutch and the motor end makes connection with the flywheel through a spur gear. (See Fig. 22*e*, p. 232.)

Two-unit Systems.—In two-unit systems the motor and generator are entirely separated. Figure 150 shows the position of the starter and the generator. The generator is driven by a chain or gear and the starter pinion engages with the flywheel.

It has been shown that the work of the generator is to convert mechanical energy into electrical energy. With the starting motor the opposite is true, as it depends for its energy upon the storage battery which, in turn, receives its supply from the generator. Electrically, the starting motor is connected to the battery through a heavy cable and a starting switch; mechanically, it is connected to the engine through a drive. When the starting switch has been closed the electrical energy stored in the battery is transmitted instantly to the motor through its

fields and brushes, causing the armature to rotate and transmit this mechanical energy to the engine through the drive, flywheel, and crank shaft.

Starter Clutch or Drive.—The clutch shown in Fig. 153 is used with the type of starter installation shown in Fig. 152. The clutch is located at the forward end of the crank shaft, and a roller chain between the starter sprocket and the clutch sprocket connects them. The clutch

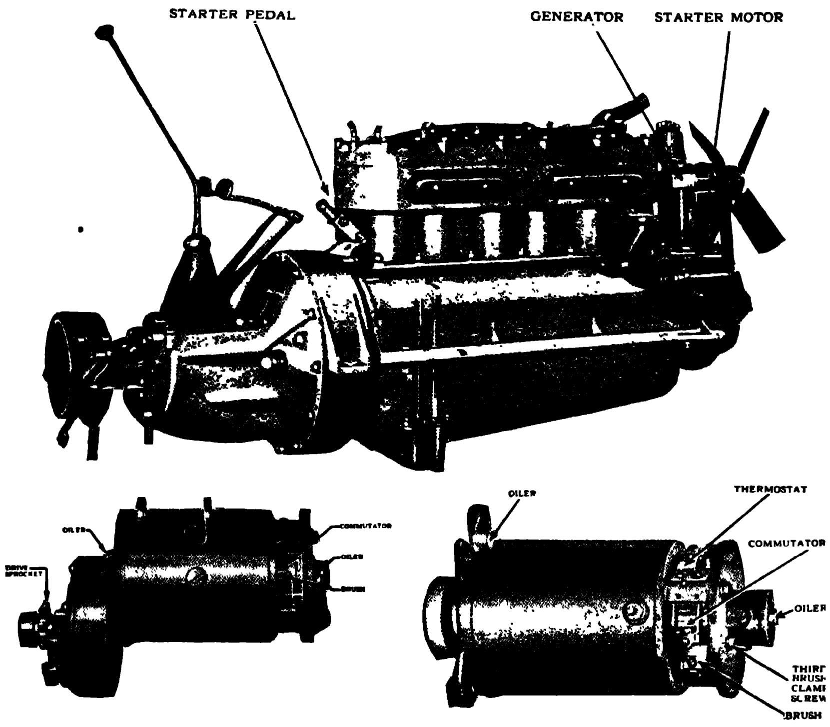


FIG. 152.—Starter and Generator Mounting and Individual Units. (Studebaker Big-six.)

consists of a drop-forged hub in which is inserted a hardened steel ring. Within this ring and revolving on a phosphor-bronze bushing around the crank shaft is a tool-steel spider to which is bolted a large sprocket which is driven by a chain from the starting motor. Located on the spider at equal distances apart are three recesses in which are fitted wedge-shaped pawls which conform in shape to the radius of the steel ring in the clutch hub. When starting, these pawls bear against this ring, gripping very firmly and cranking the engine. When the engine starts under its own

power the pawls automatically release, owing to the fact that the crank shaft revolves faster than the spider. When the engine is in motion the sprocket, spider, and chain remain idle.

In Job No. 25, Chapter III, is shown an over-running clutch using rollers. This type is usually connected between the motor generator and the pump shaft. It releases when the unit is operating as a starter and engages when the engine picks up speed.

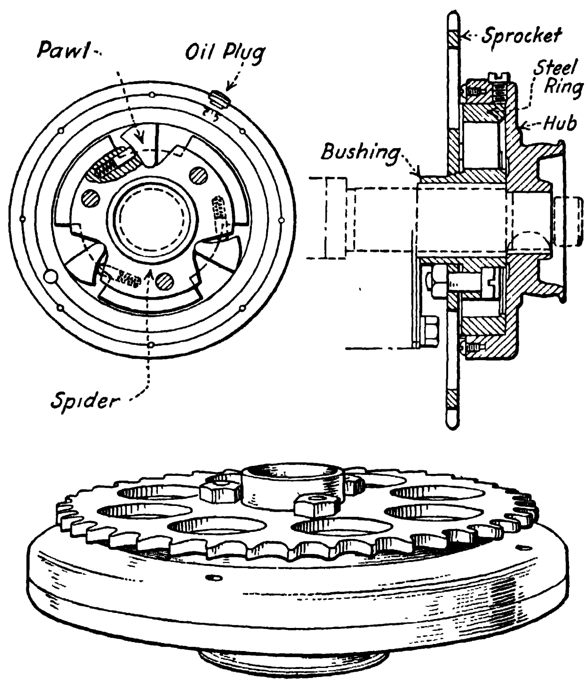


Fig. 153.—Pawl Clutch.

Figure 155 shows a starter and its driving mechanism. The pinion is shifted into mesh when the foot pedal is pressed down.

To perform this driving function, a number of different clutch devices are employed, such as the worm and wheel, inertia clutch, friction clutch, pawl and ratchet, roller clutch, jaw clutch, and Bendix drive. The most satisfactory must be positive in action and noiseless. The clutch on starting motors must be durable and able to withstand sudden strains.

Bendix Drive.—With the Bendix drive (Fig. 156) the power developed by the starting motor is transmitted to the engine flywheel through an automatic screw shift pinion which is mounted on an extension of

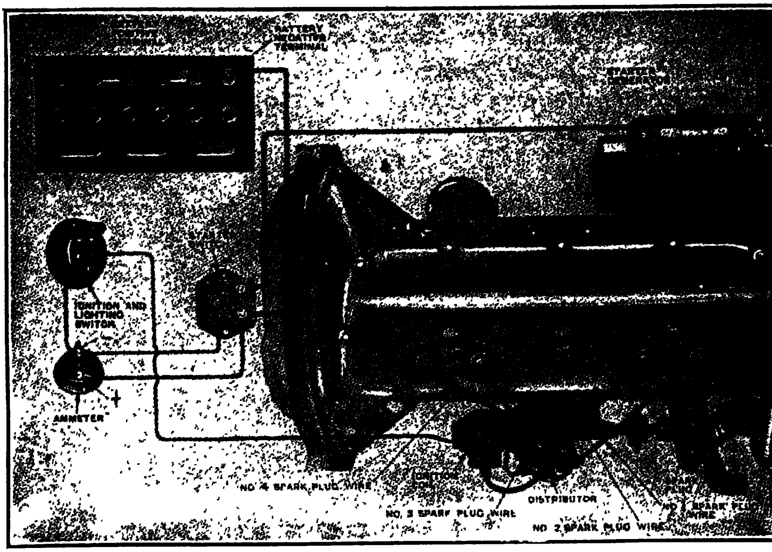


Fig. 154.—Single-unit Starter-generator Mounting, Circuits, Drive Chain, and Chain Adjustments. (North East-Dodge.)

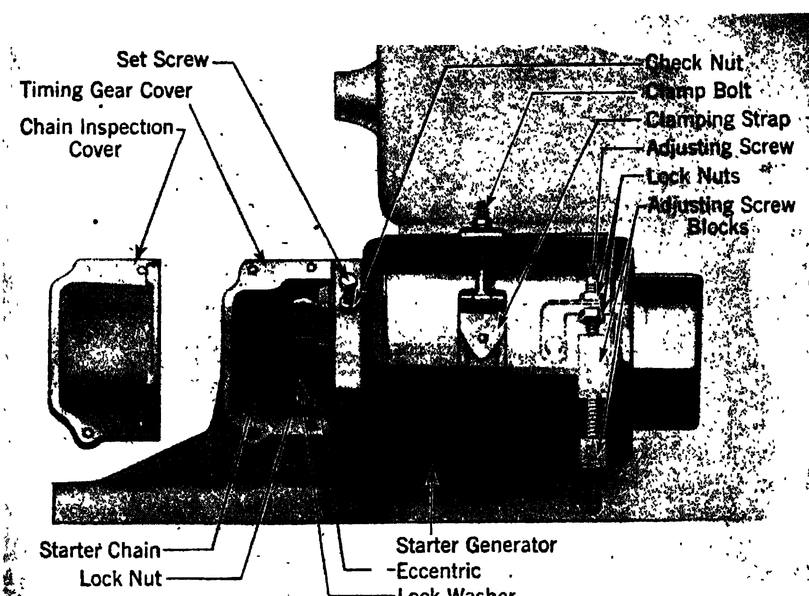


Fig. 154a.—North East Starter-generator Showing Starter Chain.

the armature shaft. It consists of a threaded sleeve, weighted screw gear, drive spring, and drive head.

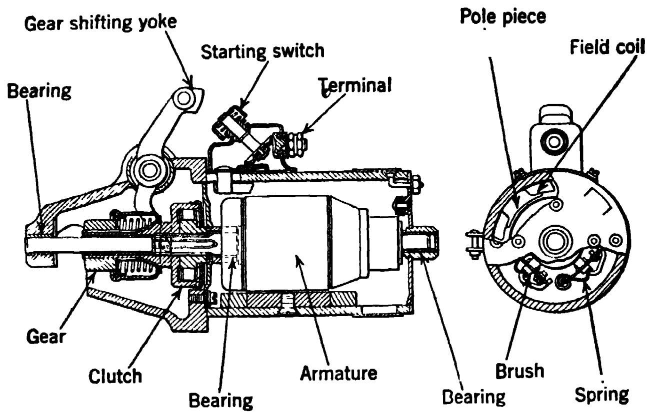


FIG. 155.—Starter Motor with Mechanical Engagement of Pinion and Flywheel Gear. (Marmon.)

When the starting switch is off, the pinion is at rest on the rear end of the threaded sleeve. Closing the starting switch impresses full battery voltage on the motor and it immediately begins rotating. As the

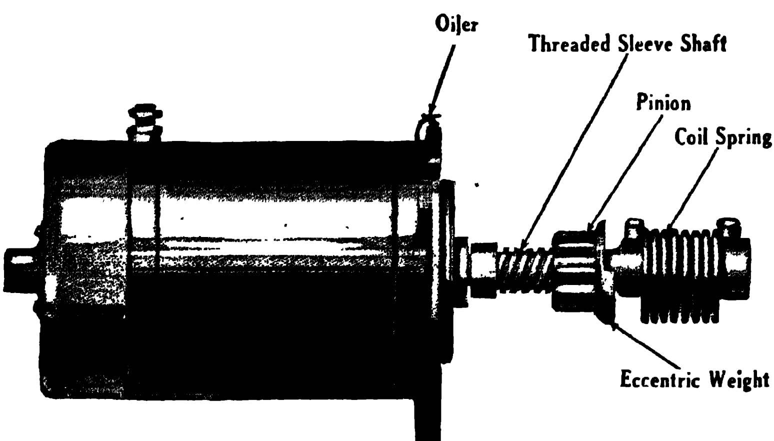


FIG. 156.—Bendix Drive on Starting Motor.

load is not large enough to compress the spring when the motor starts, the threaded sleeve is immediately revolved by the spring in release position. The counterweight prevents the screw pinion from revolving;

hence, by virtue of the revolving thread, the pinion moves forward on the sleeve until it reaches the flywheel. The spring allows the pinion to revolve until it reaches the flywheel. When the pinion is fully meshed into the flywheel teeth, the spring compresses, absorbing the impact caused by the sudden engagement with the engine which is idle, and the pinion is then revolved as through a continuous shaft, turning the engine over. When the engine fires, the speed of the flywheel exceeds that of the driving pinion and screws the latter out of mesh back along the threaded sleeve to its original position.

The drives most commonly used to connect the starting motor to the flywheel are: (1) The Bendix drive (Fig. 156); (2) the sliding pinion used on Delco single unit systems, Buick cars (Fig. 22*e*, p. 232); and the starters of two-unit systems employed on numerous cars (Fig. 155).

Lighting.—It is necessary to use a storage battery where lights are required when the car is standing still. The storage battery must be kept charged. The lighting system includes the generator, the storage battery, the light wiring, and, in addition, switches, fuses, the automatic cutout devices.

The lamps installed on a car are of the right capacity to suit its needs. When lamps of larger capacity are installed in order to get brilliant lights or when " spot " lights are added, there is an additional drain on the battery and care should be taken to protect it from becoming discharged.

The lamps require little attention other than cleaning. Most systems use 6- to 8-volt lamps connected in parallel with each other. Frequently the dash and tail lights are connected in series. Where two lamps are connected in series, if one burns out both are extinguished.

STARTING MOTOR TROUBLES

Test Procedure

CASE I.—Starting motor shows no life whatever.

1. Turn on the lights and try starter. If lights do not dim, look for
   (*a*) open circuit in
      (1) Starting switch.
      (2) Motor terminals.
      (3) Starter ground connection to frame of car.
   (*b*) Dirty or glazed commutator.
2. Remove and examine brushes carefully.
   (*a*) Brushes worn out.
   (*b*) Brushes not bearing on commutator.
   (*c*) Brush material of too high resistance.

3. If ammeter shows no reading when lights are switched on, if starting motor kicks over spasmodically or not at all, or if lights do not dim when starting button is depressed, examine
   - (a) Internal motor circuit.
     - (1) Field or armature coils.
     - (2) Check for open circuit in armature where coils are soldered to commutator segments.
   - (b) External motor circuit.
     - (1) To frame.
     - (2) In defective starting switch.
4. If ammeter needle flickers, examine for loose contacts.

CASE II.—Starting motor shows some life but not enough to turn engine over.

1. Turn engine over by hand. If this is impossible, look for engine trouble.
   - (a) Bad engine bearings, especially if bearings are of the smooth type.
   - (b) New bearings not worn in.
   - (c) Bendix drive stuck in flywheel.
2. If engine is free, look for
   - (a) Poor contact at battery terminals.
   - (b) High-resistance contact at brushes.
   - (c) Poor connection between brush and shunt.
   - (d) Poor connection between shunt and brush-holder.
   - (e) All brushes not bearing on commutator.
   - (f) Brushes stuck in brush-holder.
   - (g) Grounded brush-holder.
   - (h) Loose ground connection (if ground return system).
   - (i) Battery below cranking capacity.
   - (j) Open circuit in armature coils.
3. Disconnect battery and make temporary connection to a fully charged storage battery. If starting motor will then turn engine over, the battery in the car is at fault.
4. Test storage battery with hydrometer.* If storage battery is low, test generator.

* NOTE.—Always make hydrometer reading before adding distilled water.

5. If battery is low or lights are dim, test out ampere charging rate of generator. (Do not rely upon ammeter on car.)

CASE III.—Lights and spark are cut off entirely when starting switch is depressed.

Examine for short circuit in
   - (a) Starting switch.
   - (b) Motor wiring.
   - (c) Motor itself.

Procedure if Generator is at Fault

1. Test for open circuit in
   - (a) Generator terminals.
   - (b) Battery connection.

(c) Ground connection to car frame (if grounded return system.)
(d) Fuse.
(e) "Cut out" or ignition switch.

2. Test for short circuit in
   (a) Generator itself.
   (b) In wiring.
3. Examine brushes for
   (a) Pitted or burned faces.
   (b) Dirty or glazed commutator.
   (c) High-resistance contact at brushes.
   (d) Worn-out brushes.
   (e) Poor connections.
   (f) Brushes not bearing on commutator (faulty spring or holder).
   (g) Shorted brush-holder insulation.
4. Examine generator for
   (a) Worn bearings causing unequal air-gap.
   (b) Defective armature.
5. Examine regulator and cutout relay for
   (a) Dirty contacts.
   (b) Contacts out of adjustment.
   (c) Regulator cuts out too soon or not soon enough owing to gummed mechanical parts.
   (d) If third-brush regulation is used, see brush connection or look for defective mechanism.

Questions.

1. What are the reasons for the universal adoption of the electrical starter by automobile builders?
2. What are the parts of an electrical starter?
3. What is a unit system?
4. What is a motor-generator system?
5. What are the principal types of starting and lighting systems?
6. How is the magnetic field of a motor produced?
7. Are starting motors series or shunt wound?
8. What is an over-running clutch?
9. Explain the action of a Bendix Drive.
10. Why are fuses used in the electrical system?
11. Describe the action of a pawl clutch.
12. What types of clutches are used to engage the starting motor with the flywheel?
13. Will loose or dirty battery terminals become warm, if the starter button is pressed? Why?

CHAPTER XIII

ENGINE FUELS

So far as their fuel qualities are concerned, many substances—wood, coal, or crude petroleum—could be used in combustion engines. The difficulty is purely of a mechanical nature. The fuel to be satisfactory must be in such a condition that it becomes combustible when mixed with air. That is, it must be a mixture which when ignited will burn almost instantaneously and leave practically no residue or ash. Research chemists are trying to find new and cheaper fuels which will meet the increasing demands on our decreasing supply of pertoleum products.

Gasoline.[1]—Gasoline is a physical blend of hydrocarbons, all of which are sufficiently volatile to form an explosive when mixed with the proper proportion of air.

Gasoline is derived from crude petroleum, which is widely distributed in the different countries of the world. The characteristics of crude oils vary according to the localities from which they come; consequently, gasolines made from them do not closely resemble each other, although to the layman they may look very much alike.

For convenience, all gasolines may be classified under four heads: (1) "natural," (2) "cracked," (3) "by-product," and (4) "casing-head."

The so-called "natural" gasolines are recovered from the first distillation of petroleum in "crude" stills. Gasolines are recovered as by-products from other processes of refining, but, as a whole, they do not resemble closely the "natural" or straight-run gasoline. From still another source, gasolines are recovered by compressing and condensing under pressure gases coming from crude-oil wells. Sometimes these gases are made to bubble through heavy oils which absorb the condensable portion, and subsequent distillation liberates the very light gasoline which they hold in solution. These volatile compounds are known as "casinghead" gasolines. They are more volatile than other gasolines on the market and are seldom used without blending. If employed in

[1] Permission to use this discussion of fuels first published in Veedol, is given by the Tidewater Oil Company.

the form in which they are recovered, the evaporation losses in handling are so high as to render them uneconomical for use. Very volatile gasolines are recovered from the gases coming from crude-oil and other stills.

The well-known brands of gasoline now on the market are mostly mixtures of gasolines obtained from different sources. These gasolines are mixed in such a way as to give the correct volatile properties required of engine fuels. In general they are as uniform in physical and chemical properties as production methods will permit. For all practical purposes they may be considered as perfectly uniform in fuel value.

Many of the large refiners change the volatility of their gasolines with the summer and winter seasons. It is possible to utilize heavier gasolines in summer than in winter and, naturally, oil refiners are ready to take full advantage of this fact, as the total output of engine fuel can be greatly increased thereby, to the advantage of both the consumer and the producer.

Gasolines adulterated with kerosene are also sold as gasoline, but mixtures of this sort are to be avoided for many reasons hereinafter given.

Many efforts have been made to arrive at an acceptable specification for the identification of engine fuel to be known as gasoline, but as yet such a specification has not met with the universal approval of oil refiners. Much valuable work of this nature has been done, however, and the study of various fuels for use in internal combustion engines has brought to light at least the necessary requirements of such fuels from the viewpoint of volatility, purity, and chemical and physical characteristics. It has been definitely decided that gravity alone does not indicate the quality of gasoline.

All gasolines should be sufficiently volatile to make possible the easy starting of the motor at average temperatures. In considering the subject of gasolines the most important point to bear in mind is that these hydrocarbon fuels are mixtures of different compounds which boil at different temperatures. It is unnecessary that the entire body of the gasoline be sufficiently volatile to evaporate readily and completely at ordinary temperatures. To meet service conditions, however, there must be a sufficient quantity of volatile constituents present to form an explosive mixture with air and thus start the engine. Once the engine is running, carburetion is much easier because of the heat conditions of operation.

The function performed by these "light ends" in a motor fuel is the same as that of kindling wood in starting a fire. Kerosene contains no "kindling wood," and heavy gasolines contain only a small amount which is insufficient for starting. Therefore, neither kerosene, heavy

gasoline, nor a mixture of heavy gasoline and kerosene can be used satisfactorily in an automobile engine or in any other variable-speed, variable-load engine.

To continue the analogy: Satisfactory engine fuels may be said to consist of kindling wood, cord wood, and a lump of coal. This lump of coal or "heavy ends" can never be eliminated commercially in the manufacture of gasolines. In the best gasolines it is very small and increases in size until it represents a large portion of the motor fuel charge when kerosene is mixed with gasoline.

It is important for the automobile user to know whether the heavy ends in his gasoline are made up of hard coal or soft coal and just how big is the lump of coal. In other words, he should know, in a practical way, the temperature at which the heavy ends of his gasoline boil. If the temperature is high the heavy ends will not be vaporized in the engine, but will wash off the lubricating oils from the cylinder walls and be blown down to the crank case or partially burned in the explosion chamber and leave behind most or all of the carbon contained in them.

It is needless to point out the destructive effect on bearings and cylinders caused by gasoline contamination of the lubricating oil in the crank case.

The total consumption of gasoline in all types of engines has increased to such an unprecedented volume that it is economically impossible for oil refiners to furnish motorists and other users with "gilt-edged," highly volatile "natural" gasoline. The well-known brands of gasolines now on the market (especially those having a national distribution) are not as highly volatile as the "natural" gasolines obtained in much smaller quantities in the past.

When the automotive industry was in its infancy, engineers thought that it was impossible to use any fuel heavier than our present-day "casinghead" gasolines. So many improvements have been made in engines, carburetors, and preheating devices that the ultra-volatile gasolines are no longer required, nor are they useful. Most of the gasolines now on the market are perfectly satisfactory for general use, *provided* the carburetor equipment of the engine has been designed for properly atomizing and vaporizing our present-day heavier fuels.

It is clearly a national duty of engine and automobile manufacturers to bend all their efforts toward the development and perfection of gasoline engines which will burn heavy fuels just as satisfactorily as the lighter, more expensive kinds. The manufacturer who is able to do this has a strong sales argument in his favor. It is a distinct proof of reduced operating costs if the manufacturer can truthfully tell the automobile user that his engine equipment will economically handle heavy fuels

without the numerous drawbacks which are often associated with the burning of such fuels.

Preheating.—A modern automobile engine should have proper provision for heating the incoming atomized charge of gasoline and air. This may be accomplished in many ways—(1) a hot-air inlet to the carburetor, (2) a hot-water jacketed mixing chamber, (3) a hot-water jacketed manifold, (4) a manifold cast integral in the cylinder block leading from the carburetor to the inlet valves, (5) a manifold integral with the exhaust, and (6) an electrical warmer.

The regulation of the hot air fed to the carburetor is very easy of attainment, as is also that of the quantity of hot water circulating through either jacketed inlet manifold or carburetor jackets.

Briefly the methods just enumerated are given to show how additional heat is applied to our heavy gasolines so as to render them sufficiently volatile to form the desired explosive mixtures required in service. When properly preheated, present-day gasoline will give as many miles per gallon and as satisfactory service as the more volatile gasolines sold a few years ago.

Since the best of service and the maximum number of miles per gallon can be obtained only by preheating the fuel mixture to a certain degree, it is important that the user be careful to see that his engine is properly equipped before the gasoline is condemned as bad.

Motorists should base their judgment of gasoline quality and serviceability upon (1) the ease with which an engine may be started in cold weather, (2) the miles per gallon obtained from the fuel, (3) the carbon-free conditions of the explosion chambers, (4) the freedom from gasoline contamination of the oil in the crank case. In this connection it is necessary, of course, to assume correct carburetor adjustment.

Benzol.—Benzol is a liquid product of coal-tar distillation. Commercial " 90 benzol " consists chiefly of benzene mixed with a small percentage of other coal-tar derivatives. Benzol was first recovered as a by-product in the manufacture of illuminating gas and its importance as a chemical compound was not appreciated fully until the discovery of coal-tar dyes and high explosives. From this period on, the consumption of benzol for the manufacture of the latter greatly increased. In some foreign countries benzol has been used as an engine fuel for omnibuses and taxicabs. In Europe a blend of 50–50 benzol and alcohol is used with very excellent results as an engine fuel, since this fuel can be used in the ordinary engine without change of compression ratio.

Recent experiments in aviation engines show that a mixture of very

light gasoline with benzol furnishes an excellent fuel for use at high altitudes.

Distillate.—The distillate here referred to is that produced from California and other Western crudes which contain a relatively small amount of illuminating oil. The boiling point of distillate lies between that of medium-grade gasoline and refined kerosene. It requires about the same degree of preheating as does benzol for its vaporization and gives approximately the same efficiency.

In the West distillate is widely used in commercial vehicles, as well as in farm tractors and small stationary engines.

Kerosene.—Illuminating oils or kerosenes are much less volatile than benzol or distillate, and therefore require a strong preheating to produce rapid evaporation. Used in engines running under constant loads and speeds, kerosenes are slightly less efficient volumetrically than distillate.

Although kerosene is a very unsatisfactory fuel for use in engines operated under conditions of variable speeds and loads, it is now used quite extensively as one of the cheapest fuels for farm tractor engines, which operate at fairly constant loads and speeds. In these engines, however, it is necessary to inject water, continuously or intermittently, into the cylinders with the charge, for the purpose of preventing heavy carbon deposits and also for softening the violence of the explosion.

In this connection kerosene fuel users should never lose sight of the important fact that water injection produces moist-cylinder conditions within the engine. To meet properly these moist-cylinder conditions the use of a blended oil is highly recommended.

Alcohol.—Denatured alcohol contains a little more than half as much fuel value per pound as gasoline. This means that in order to use alcohol as a fuel, larger openings in the carburetor must be provided. Because of its corroding qualities, wood alcohol is not suitable for a fuel. Tests show that it requires about 1.8 times as much alcohol to operate a gas engine as gasoline.

The principal thing which keeps alcohol from becoming a common fuel is the cost of manufacture.

Naphthalene or " camphor balls " is a type of solid fuel which has been used in Europe. It is first melted to a liquid, vaporized, and then mixed with air.

CHAPTER XIV

CARBURETORS

Theory of Carburetion.—The carburetor is a mechanical stoker which prepares, measures, and delivers the fuel in the engine. The degree to which a carburetor is able to receive commercial fuels and to perform efficiently its functions measures its own value as a part of the engine equipment. Of necessity, many improvements have been made in carburetor construction, not only because of natural development in efficiency but also because of the changing quality of gasoline.

A number of good types of carburetors are being used by different manufacturers. The general principles of carburetion are the same for all, but the method by which a carburetor receives the fuel, prepares it for use, and delivers it to the engine differs in the various types. A description of the construction and adjustment of several types are included as typical of the theory and operation of all. The repairman or owner should consult the manufacturers' instruction book for specific directions for fine adjustment, since types are changing with new models and the number of types is so great it is unwise to attempt to include a description of all.

All carburetors of to-day are constructed with float feeds and use the spraying device to break up the fuel. The admission of gasoline to the float chamber is controlled by the action of the float upon a needle valve. The float chamber provides a supply of gasoline to the spraying nozzle. The suction of the intake stroke pulls the gasoline from the carburetor float chamber through the spraying nozzle into the mixing chamber where it is mixed with the correct proportion of air and is then drawn through the intake manifold into the cylinder.

The supply of mixture must be varied to suit the power required. The quantity of mixture is measured by a butterfly valve which is placed in the passageway of the mixing chamber.

Needle Valves and Spray Nozzles are an important part of the carburetor since they not only measure the gasoline supply to the mixing chamber but also break it up into a spray so that it is readily vaporized.

The types in common use include (1) a simple opening through which the gasoline is drawn; (2) an opening which has a vent cap having a

series of small openings; (3) a simple opening which has an internal adjustable needle on the inside which varies the amount of gasoline and assists in making a spray; (4) an opening with an external adjustable needle which performs the same functions as in (3).

The adjustment of a carburetor consists of regulating the supply of gasoline and air so that the mixture will give the best results under varying speed conditions. As a general rule, low-speed adjustment with the spark retarded is made first in order to regulate the gas nozzle or special low-speed adjustment, and then the high-speed adjustment with spark advanced to running position is made by regulating air adjustments and

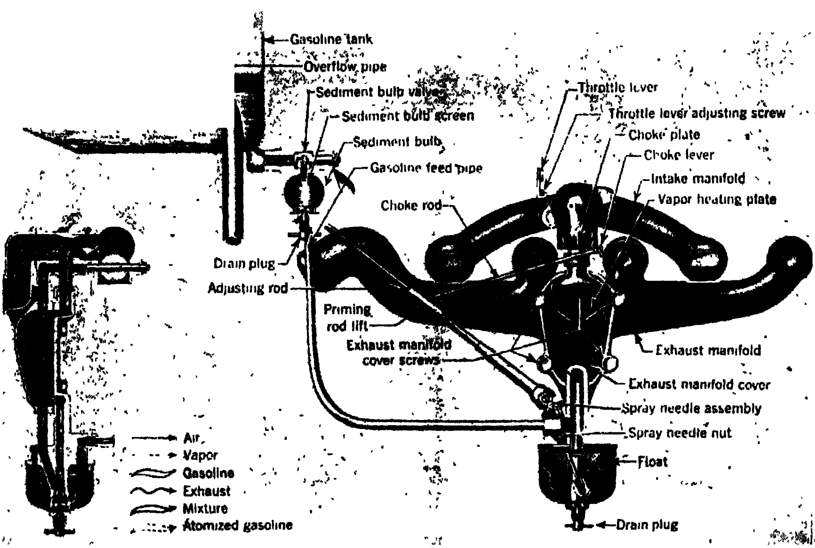


FIG. 157.—Gasoline System on the Ford Car. (Model T.)

needle valves. Specific directions are necessary for each type of carburetor since each has its own individual construction for obtaining a correct mixture.

The importance of correct carburetion is shown in Fig. 158. The fact that but $12\frac{1}{2}$ per cent of the gasoline consumed in an automobile engine goes into useful work in developing power to overcome the air resistance, to climb hills, to accelerate, and to serve as a reserve power, emphasizes the need for careful attention to carburetor adjustment.

Ball and Ball Carburetor.—Figure 159 shows a Ball and Ball carburetor. Figure 160 is a vertical section showing the relation of the gas level in the float chamber to the spray nozzle.

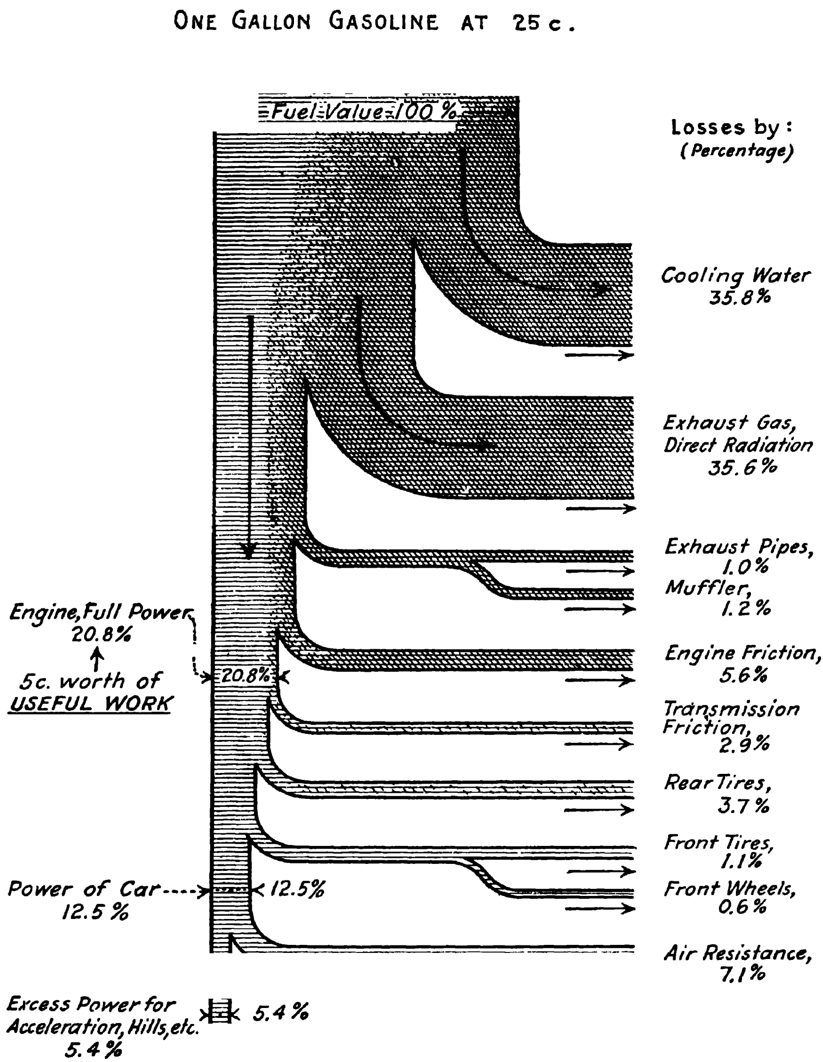


FIG. 158.—Losses of Fuel in Automotive Engines.

The only adjustment that the public can make is the idling adjustment, which produces no effect whatever on the running of the car, except when the throttle is closed to the idling position. This idling

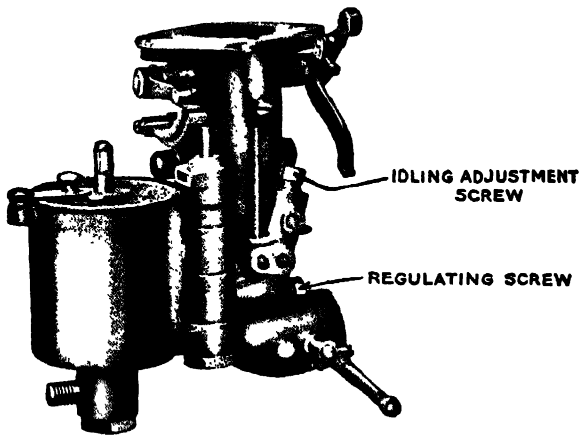


FIG. 159.—Ball and Ball Carburetor.

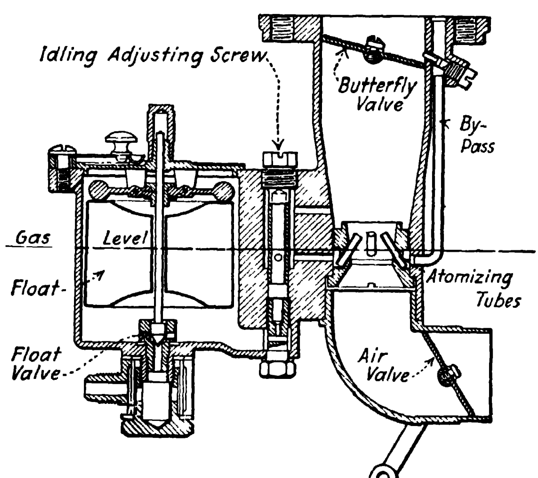


FIG. 160.—Section of Ball and Ball Carburetor.

adjustment is shown in Figs. 159 and 160. Unscrewing makes the idling quality leaner, tightening the screw makes it richer.

The richness of the mixture at all speeds above idling is determined by calibrated regulating openings in the regulating screws, one of which

is shown in Fig. 160. Numbers stamped on the heads of these screws indicate the diameter of the regulating openings in hundredths of a millimeter.

Stromberg Carburetor.—This carburetor is of the plain tube type (Fig. 161), so called because it has no air valves or metering needles. Both the air passage and gasoline jet are of fixed size for all engine speeds.

The idling mixture and closed throttle running up to above 8 miles per hour are controlled by the upper knurled button or idle adjustment

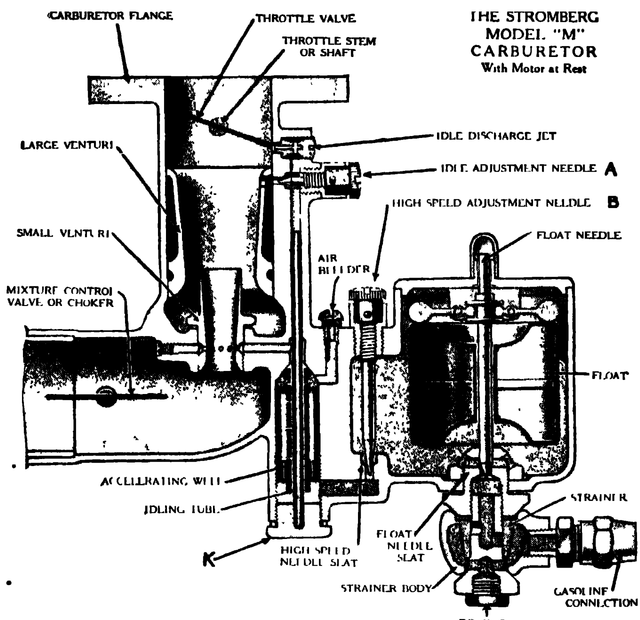


Fig. 161.—Stromberg Carburetor.

screw *A*. This operates on the air so that screwing it in gives a richer mixture and screwing it out gives a leaner mixture.

To make this adjustment, turn screw *A* outward until the engine slows down, then turn *A* in notch by notch until the proper idling mixture is reached. Care should be taken not to slow down the engine by too rich a mixture, by screwing *A* in too far. When the engine is idling properly there should be a steady hiss in the carburetor. If there is a weak cylinder or a manifold leak, the hiss may be unsteady.

If after making the idling adjustment as previously described, the engine idles too fast, turn the small throttle stop screw *A* (Fig. 161), to

the left or counter-clockwise until the proper idling speed is reached. If the motor idles too slowly and stops, turn the screw *A* (Fig. 161), to the right, or clockwise, until the proper speed is reached. Before adjusting the throttle stop screw, it will be necessary to loosen the lock screw.

The High Speed and main driving adjustment is regulated by the high-speed needle *B* which regulates the opening through which the fuel flows to the jet. Turning *B* to the left counter-clockwise gives more gasoline, to the right or clockwise, less gasoline.

To make the proper high-speed adjustment, advance the spark lever to normal driving position, set the throttle lever on the steering wheel at a position which will give about 25 miles an hour speed on a smooth road, then adjust the high-speed needle to the minimum opening that will give the greatest engine speed for that throttle opening. This should give a good average adjustment. Two or three notches less may give the best economy for continuous driving or touring, and two or three notches to the left may be best for short runs in cold weather when the engine does not get up to normal heat.

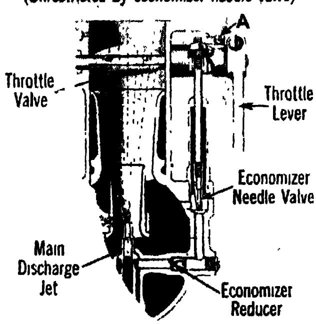


Fig. 162.—Stromberg Economizer.

To prevent a wrong high-speed adjustment from giving a harmful rich mixture, a gasoline nozzle reducer is inserted beyond the high-speed needle opening, in the base of the discharge jet above the plug *K*. The reducer placed in the carburetor at the factory will permit about 20 per cent more gas to pass through than is needed generally. However, under some conditions, a larger reducer may be needed in order to secure a richer mixture. These reducers may be obtained from the Stromberg factory or the nearest Stromberg Service Station.

The Economizer Device, shown in Fig. 162, is on some of the Stromberg carburetors and operates automatically to keep the mixture lean at speeds of from 10 to 45 miles per hour. The economizer needle is set properly at the time the carburetor is installed on the engine, and no adjustment is needed.

In all cases adjustments should be made when the motometer shows a temperature higher than 140° F., and the richer adjustment necessary for a cold engine should be obtained by using the driving control or choker.

Carter Carburetor.—To adjust a Carter carburetor, follow the instructions given. When adjusting the idling mixture, open the idle adjustment screw *A* from $\frac{3}{4}$ to $1\frac{1}{4}$ turns or until the engine hits evenly without loading or missing. Turning this screw clockwise gives a richer mixture. After a proper adjustment for low speed is obtained, set the high-speed adjustment as follows: Back out high-speed adjusting needle *B*, 1 to $1\frac{1}{4}$ turns from its closed position, and set the adjustment so that the engine will accelerate without "spitting" or "loading." The best results in both performance and economy are obtained by setting the mixture as lean as possible. The high-speed adjustment screws outward to produce a richer mixture. The high-speed needle can be set to secure any mixture ratio desired by the operator.

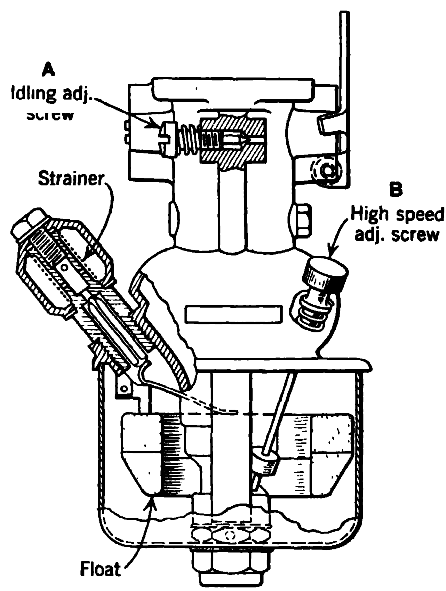


FIG. 163.—Carter Carburetor. (Model D.R.O.)

The model RXO Carter carburetor, used on the Chevrolet automobile, is a set carburetor and to adjust high speed it is necessary to change the jets.

Zenith Carburetor.—Figure 1*h*, page 256, in Chapter IV on Trouble Shooting, and the accompanying text illustrate the construction and adjustment of Zenith carburetors.

Stewart Carburetor.—Figure 164 shows a section of the carburetor used on the Dodge and Essex cars. From the first chamber the gasoline flows through a small passage over to the compartment at the base of the metering pin. It fills this compartment and rises part way up the aspirating tube. The suction created by the downward travel of the pistons in the cylinders causes the air to rush into the mixing chamber around the aspirating tube and draw up the gasoline, vaporizing it in this mixing chamber. The air inlet to the carburetor is a short tube to the chamber between cylinders 2 and 3, which in turn is connected by another short tube to the hot-air stove on the exterior of the exhaust manifold.

There is an automatic air valve in the carburetor designed in such a way that it is lifted off its seat by the suction of the pistons in the engine

and thus supplies the proper proportion of air and gasoline at all speeds. At low speeds all the air needed is drawn through the air holes drilled in the air valve around the aspirating tube. As the engine speeds up, the suction is increased in the carburetor and hence the automatic valve is lifted, thus allowing a greater supply of air to be drawn into the round mixing chamber. As the air valve is lifted the amount of gasoline is increased automatically by the raised position of the aspirating tube in reference to the tapered metering pin. Hence the higher up the aspirating tube or spray nozzle the greater the supply of gasoline that can get between it and the tapered metering pin located in this tube. The taper of this metering pin has been very carefully designed in order that the correct mixture of air and gasoline may be obtained at all speeds.

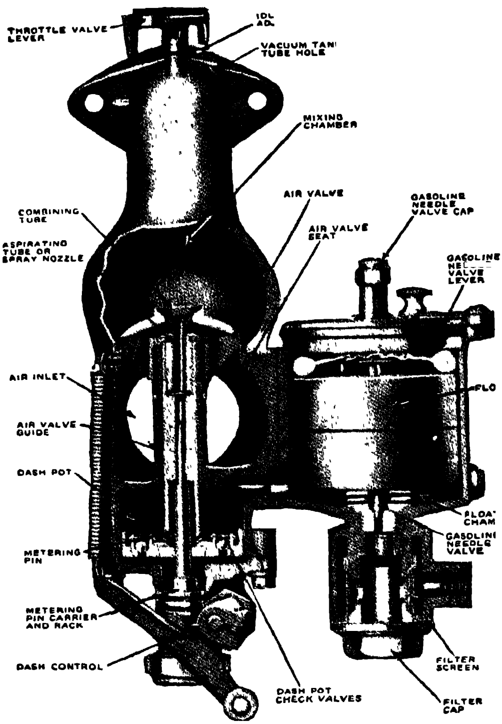


FIG. 164.—Section of Stewart Carburetor.

There is but one point of adjustment to the carburetor. This adjustment varies the relative height of the metering pin to the opening of the aspirating tube or spray nozzle when the dash-control ratchet on the instrument board is in its regular running position. This adjustment is properly made at the factory and should not be changed unless it is known to be incorrect.

The tapered metering pin is subject to control within fixed limits by means of the dash-control ratchet located on the instrument board for the purpose of obtaining a rich mixture for starting. Should there be any reason for changing the fixed adjustment of the tapered metering pin, it can be done by turning the stop screw to the right or to the left as desired. Turning this screw to the right lowers the position of the

metering pin and allows more gasoline to be admitted to the spray nozzle, thus enriching the mixture. Turning the screw to the left raises the pin, decreases the supply of gasoline, and weakens the mixture.

Tillotson Carburetor.—Figure 165 shows the Tillotson Model M, plain-tube carburetor with air-bled main nozzle, accelerating well, and by-pass for idling.

The upper cross-holes in the main nozzle *M* bleed the air above the level of the gasoline and thin out the mixture at ordinary speeds so as to give maximum economy. The lower cross-holes fill the accelerating well and empty it when the throttle is opened quickly.

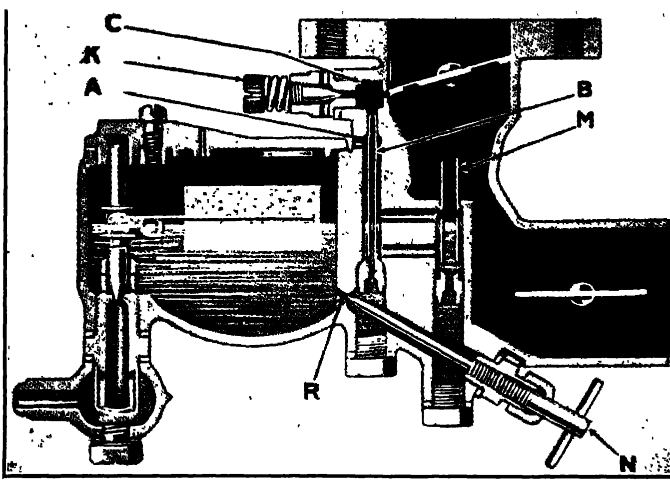


FIG. 165.—Tillotson Carburetor. (Model M.)

The needle valve *N* regulates the flow of fuel to the main nozzle. The approximate setting is two and one-fourth turns open. To adjust the carburetor, open throttle one-third on the quadrant, retard the spark, adjust the needle valve until the engine runs freely, and then close the needle valve one-eighth to one-fourth turn, which should give the best results.

The by-pass needle *K* regulates the air for idling; the approximate setting is one and one-fourth turns open. The position of the butterfly valve to give the required speed is determined by a screw which should be adjusted at the same time as the by-pass needle.

Before the carburetor is adjusted, all spark plugs, the ignition system, and the valves should be in good working order; the gasoline line and the strainer should be free and clean, and the engine well warmed up.

Vacuum Tank.—A number of devices have been used to overcome the troubles caused by lack of gasoline in the carburetor when the tanks were installed in the rear, or when they were placed under the front seat and the car was climbing a hill. In the gravity-feed system, even with the tank under the front seat, the carburetor had to be placed in a lower position than was desirable. This position made necessary a longer intake manifold, and oftentimes the carburetor was in a place where it was difficult to get to the adjustments. Where pressure systems were used with rear tanks it was difficult to maintain an even pressure, and thus the feed to the carburetor under both systems was at times uncertain and variable.

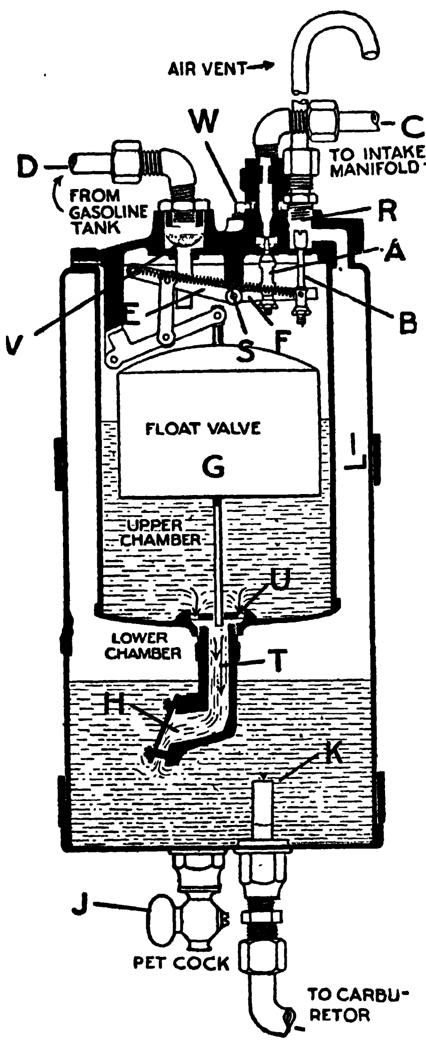


FIG. 166.—Sectional View of Vacuum Tank.

Of the several types of auxiliary tanks which have been devised to insure a constant supply of gasoline to the carburetor, the Stewart Vacuum Tank is almost universally used.

A cross-sectional view of this tank is shown in Fig. 166.

A small portion of the suction created by the downward stroke of the engine pistons is utilized to form a vacuum in the upper or filling chamber of the vacuum tank, by connecting it to the intake manifold of the engine through the small tube *C*. This vacuum closes the valve *B* and also sucks or draws up the gasoline from the main supply tank through the tube *D*, filling the upper tank to a certain level controlled by the float *G*. The float, when raised by the gasoline to the proper level, cuts

off the suction from the intake manifold by closing the suction valve A through the levers E and F, and at the same time opens the air valve B, which admits air to the filling chamber. This admission of outside air releases the vacuum, and the gasoline, owing to its weight, causes the flapper valve H to open, thus allowing the fuel to flow through the outlet T into the lower or emptying chamber. This lower chamber is always open to the outside air, thus making it possible for the gasoline to flow through the tube K to the carburetor with an even, uninterrupted gravity flow.

As the level of the gasoline in the upper tank lowers, the float falls, thus opening the suction valve and shutting the air valve, which again allows a vacuum to be created for drawing more gasoline from the main supply tank.

Carburetor Controls.—Carburetors are controlled by means of a hand-operated throttle, and by a foot accelerator. These controls open and close the butterfly valve at the entrance to the intake manifold. In starting on present-day fuels it is necessary to place an additional control which " chokes " the air supply and causes almost pure gasoline to be taken into the mixing chamber. Nearly all of these controls are placed on the dash and are adjustable as to the degree to which the auxiliary air is " choked." After the engine has started, the choke should be released as fast as the engine warms. In winter it will be necessary to use this control a great deal more than in summer.

Keeping the dash control in the starting position too long after the engine has warmed up will afford a too rich mixture, causing irregular running and overheating of the engine, and will make the fuel consumption excessive.

Heating Devices.—The refiners lower the quality of their output as the supply of crude oil decreases and as the demand for gasoline increases. The use of heavier fuels makes necessary the installation of some device to aid the carburetor in breaking up and vaporizing the fuel. While many changes have been made in the mechanical construction of the carburetor in order to break up the fuel, it has been necessary to use some sort of heating attachment to secure satisfactory carburetion. These devices include (1) flexible conduits which bring hot air from the exhaust manifold to the air intake; (2) combination intake and exhaust manifolds; (3) hot water jackets which surround the intake manifold where a single portion of the intake metal is so constructed as to be in direct contact with the exhaust manifold, thus heating the point of contact to a high temperature.

Some types of carburetors use a portion of the exhaust to heat the walls of the mixing chamber. A newer device is an electric heating coil

which is placed in the bottom of the float chamber and is used to raise the temperature of the gasoline.

Air Cleaner.—There is no question that much of the wear occurring in the various parts of an automobile engine is due to the presence of dirt and carbon. Most of the dirt finds its way into the engine through the carburetor air intake, and, since manufacturers recognize the desirability of eliminating this source of wear, most new models are equipped with an air cleaner, attached to the carburetor air intake, as in Fig. 167.

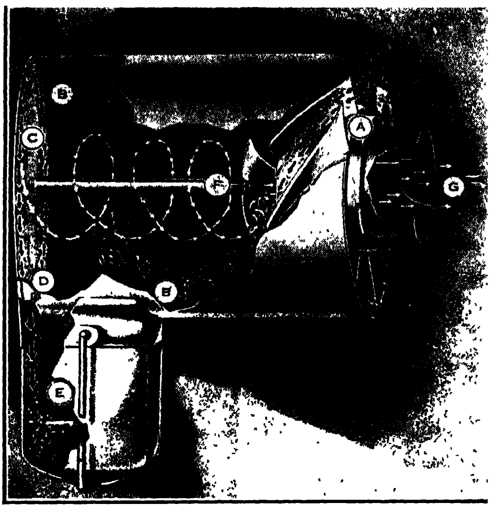


Fig. 167.—Air Cleaner.

Some air cleaners operate on much the same principle as that utilized in the ordinary cream separator; that is, a centrifugal force is used to separate two elements of different specific gravity. The operation will be readily understood from a study of Fig. 167 and from the following description:

1. The suction stroke of the engine draws the air through the directing vanes of the cleaner, which give them a rapid, rotating motion, spirally.
2. The centrifugal force separates the dust particles from the air, throwing them against the inside wall of the cleaner.
3. The spiral motion of the dust along the inside surface of the cleaner wall brings it to the rear circular end.
4. The dust is then forced through a small outlet and collects in a removable container.
5. The clean air moves spirally through the center portion of the cleaner until it strikes the directing plate and leaves the cleaner.
6. The current of clean air leaves the cleaner in a straight line and enters the carburetor.

The container at the bottom of the air cleaner, in which the particles of dust and dirt have collected, should be removed at least once during each season and emptied of dirt.

CHAPTER XV

THE COOLING SYSTEM

THE function of the cooling system is to maintain a proper temperature for the engine under all running conditions. If the engine becomes too hot or if it is not hot enough it will not operate efficiently.

Cooling systems consist chiefly of a fan (see Fig. 170), a pump to keep the water in circulation, and a radiator for cooling the water. On some cars the pump is eliminated, in which case the heat of the engine causes the water to circulate. This arrangement is known as a thermo-syphon system and is shown in Fig. 171.

Figure 158, page 479, shows that 35.8 per cent of the fuel value of the gasoline is lost through radiation. This is a direct loss in efficiency, which, with present engine construction, cannot be eliminated. It is not unlikely that automotive engineers will give much attention to this fact in the future.

Radiator.—A typical radiator consists of a tank having a large number of narrow passages in the core. The hot water from the engine

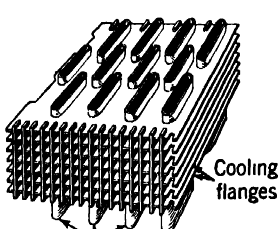


FIG. 168.—Vertical-tube Type.

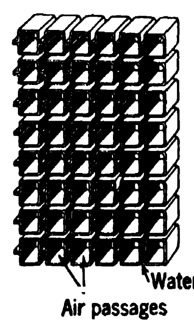


FIG. 169.—Honeycomb Type.

enters the upper opening and gradually flows through the passages in the core to the lower opening while a current of cool air is circulated through the openings in the core. An enameled shell encloses the core of the radiator. There are two popular types of radiators. One is called the vertical-tube type (Fig. 168), and the other the honeycomb (Fig. 169).

Water Pump.—A typical water pump is shown in Fig. 170.

The pump is of the centrifugal type and consists of an impeller with curved blades, fastened to the shaft, and an air-tight casing with inlet and outlet connections, fastened to the engine. As the impeller revolves, it draws water from the radiator to the center of the impeller and by centrifugal force throws it off at the outer ends of the blades and out of the casing to the cylinder jackets.

In order to keep the casing air-tight the pump shaft is carried in glands filled with prepared wick packing which also acts as a lubricant. These glands should be tightened from time to time as they show indications of leakage, but care must be taken to keep them from binding the shaft.

The Fan.—A typical fan is shown in Fig. 170. It is mounted on the front end of the motor and is driven by a belt attached to a pulley on the crank or cam shafts.

Anti-freeze Solutions.—In temperatures below freezing, it is necessary either to use an "anti-freeze" solution for cooling, or to drain the water each time the motor is allowed to cool off. Unless the car is used very little in cold weather, it is better to use an anti-freeze solution. Salts, calcium chloride, or similar solutions are likely to corrode the metal of the radiators and should be used with great care. A satisfactory solution is composed of alcohol and water, or alcohol, glycerine, and water. Denatured alcohol is preferable to wood alcohol. The proper solutions are as follows:

Alcohol. Per Cent.	Glycerine. Per Cent.	Water Per Cent.	Will Freeze at Degrees Fahr.
3	2	95	28
6	4	90	25
9	6	85	20
12	8	80	15
18	12	70	5
21	14	65	10 below zero
24	16	60	15

Water and alcohol are subject to evaporation, although glycerine tends to keep the alcohol evaporation at a minimum. When it becomes necessary to add to the solution, pay no attention to the glycerine, but add in the following proportions:

Alcohol 25 per cent—Water 75 per cent.

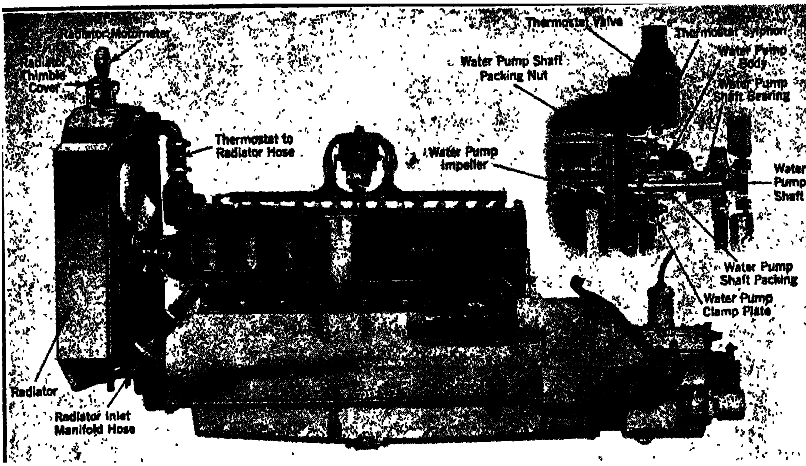


FIG. 170.—Water-pump Type Cooling System. (Packard.)

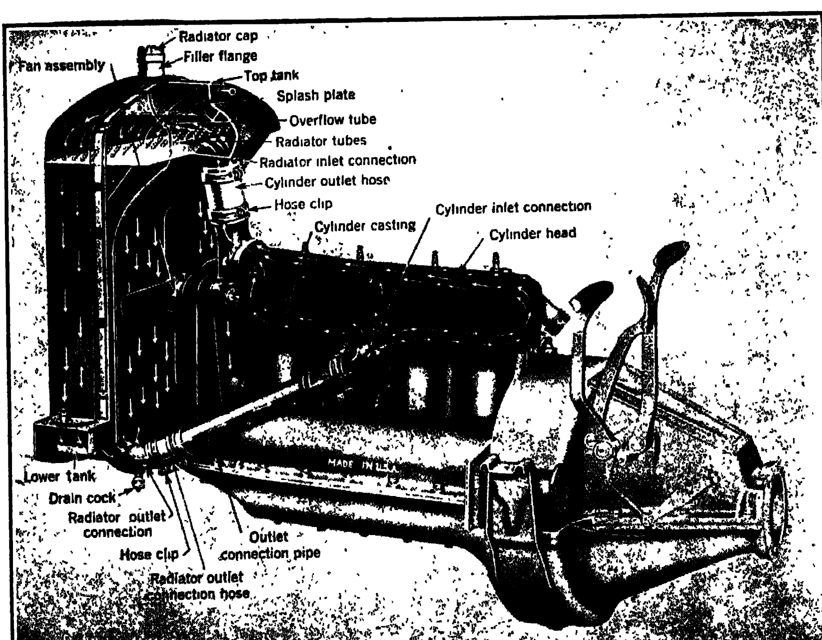


FIG. 171.—Thermo-syphon Cooling System, Showing Course of Water through Water Passages. (Ford Model T.)

A standard solution of alcohol and water has stood the test of time and has no properties that are injurious to any part of the radiator, cyl-

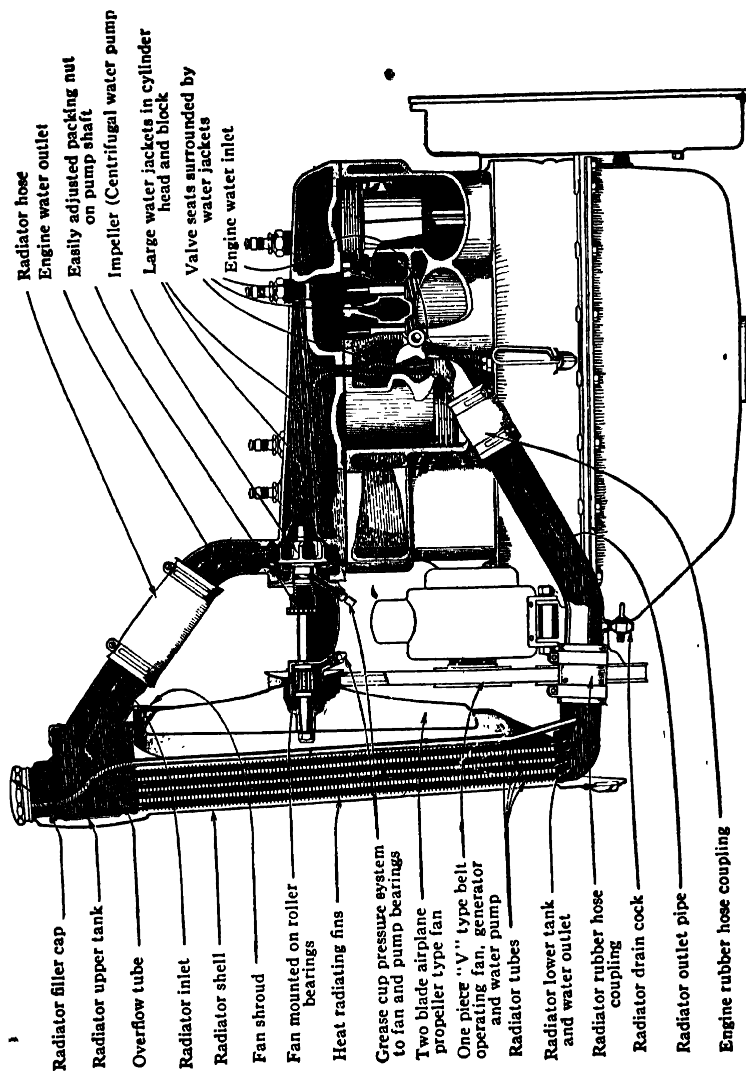


FIG. 71a Cooling ;tem on odє Ford.

inders, or connections. The freezing points of mixtures containing different percentages of wood alcohol and water are given in the following table:

Per Cent Alcohol by Volume.	Per Cent Water by Volume.	Freezing Temperature.	Specific Gravity at 70°
25	75	0° Fahr.	.969
30	70	7° below zero	.963
35	65	15°	.957
40	60	20°	.951

If denatured alcohol is used, increase the percentage of alcohol by approximately 15 per cent. That is, to lower the freezing temperature to zero degrees Fahr., 40 per cent denatured alcohol must be used. The alcohol in this solution evaporates more rapidly than the water; therefore, check up the solution frequently by testing with a hydrometer for the specific gravity; or, if no instrument is available, replace the evaporated solution with 25 per cent alcohol and 75 per cent water.

Thermostatic controls are used in some systems for the purpose of keeping the temperature of the engine at the most efficient operating point. This means that the cylinder temperatures should be kept uniform at all engine speeds. Thermostatic controls are used in all kinds of cooling systems but have been adopted universally for the water-cooled engine as the most efficient means of temperature control.

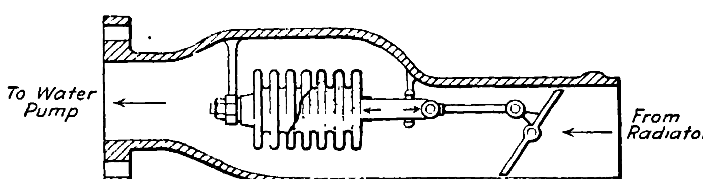


FIG. 172.—Thermostat for Regulating Temperature of Cooling Water.

Thermostatic Controls.—Thermostatic controls for the purpose of increasing the thermal efficiency, and, indirectly, of keeping down carbon deposits (Fig. 172), have been fitted to the water-circulating system in some engines. These thermostats block the free circulation of the water from the cylinder cooling jackets until the temperature of the cylinder walls and valve pockets has attained a predetermined value. With this arrangement it is claimed, (1) that the explosion chamber and cylinder walls can be maintained at a temperature sufficiently high to burn efficiently the fuel within, (2) that any reasonable oil surplus arriving above the piston heads will be flashed off, leaving practically no carbon deposit behind.

Air Cooling.—There is another method of cooling an automobile engine, and that is by air. This system has been successful on a number of makes of cars. A blower fan mounted at the front end of the crank shaft, and encased in an aluminum housing, forces air through the aluminum passageway leading over the tops of the cylinders, thence through the jackets surrounding each cylinder, and out at the rear of the engine. Deflectors direct the air in greatest volume to those points on the cylinders where most heat is developed, with the result that cylinder temperatures remain reasonably equal, even under extreme conditions.

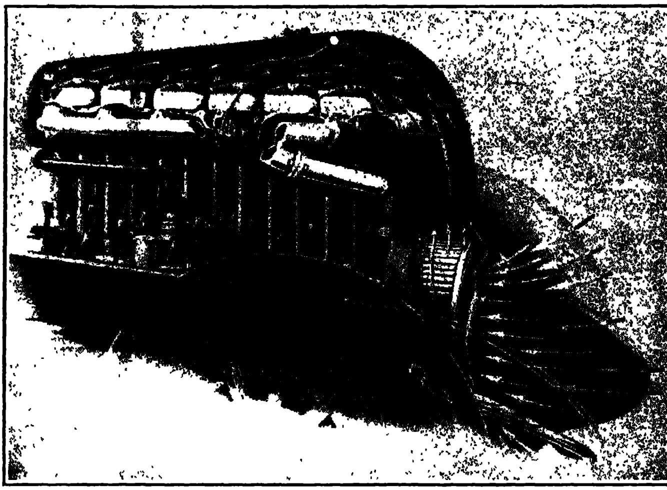


Fig. 173.—Air Cooling. (Franklin.)

CHAPTER XVI

TIRES AND TUBES

AUTOMOBILE tires are a very important part of the equipment. Nothing can cause more dissatisfaction in driving than to be annoyed by frequent tire troubles.

The satisfaction obtained from tires depends upon the attention given to them. Frequent inspection and immediate attention to cuts, bruises, and other troubles will greatly prolong the life of the pneumatic tire.

Pneumatic tires are known as clincher and straight-side types, as shown in Fig. 174. Most cars are now equipped with demountable rims. The treads are molded into various non-skid shapes.

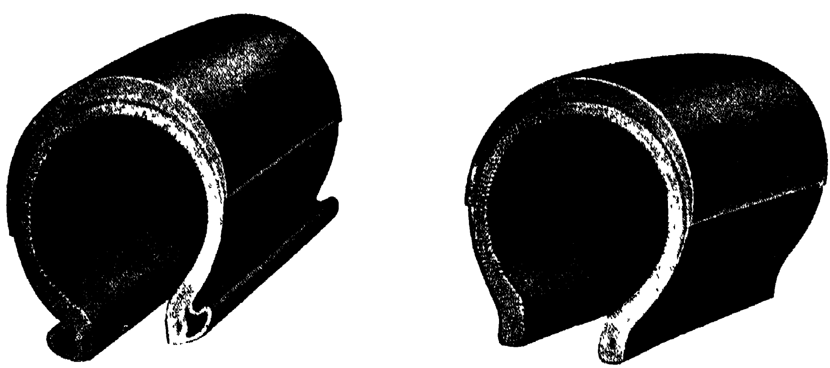


FIG. 174.—Clincher and Straight-side Tires.

Inflation.—The principal rule for the proper care of tires is to keep them inflated to the required pressure. This pressure is generally 15 pounds for each inch of cross-section in high-pressure tires. Thus a 4-inch tire should be inflated to 60 pounds, and a $4\frac{1}{2}$-inch tire to 68 pounds. The balloon or low-pressure tire should be inflated to about 6 pounds for each inch of cross-section.

Fabric and Cord Casings.—The essential difference between the cord and the fabric tire is that the main body of the cord tire consists of a number of plies of cords, each extending from bead to bead diagonally across the tread, one on top of and at right angles to the other. These

cords have a strength of 250 pounds each, are tightly twisted and bound together, and are thoroughly impregnated with rubber. This construction eliminates the working and wearing of the fabric tire due to the cross-weave and permits the tire to conform more readily to the shape of the road. At the same time they are immensely durable because of the strength of the cords and the pure gum rubber binding them together.

Injuries to Casings.—Casings may be injured in a number of ways, such as bumping into curbs, hitting bumps in the road, turning out into gutters, and other similar strains. Shocks and jolts are very likely to cause misalignment or "wobbling" of wheels, or both. When this happens the wheels travel with a skidding action which wears down treads very rapidly, even if the irregularity is so slight that the eye can hardly detect it. The wheels should be tested frequently to make sure that they run true.

FIG. 175.—A Cut Casing.

Probably as many as one car in three has one or more misaligned or wobbly wheels, robbing the tires of thousands of miles of service.

Flat tires, rim cuts, bruises and glass cuts are frequent sources of injury to the rubber tread, and eventually result in a puncture or blowout. Figure 175 shows a tread cut which, if not repaired, will soon enlarge and ruin the casing.

Flat Tires.—Under-inflated tires are more subject to bruises and rim cuts than those that are kept inflated at the standard pressure. The constant flattening of the casing when not fully inflated also causes additional heat to develop. A piece of wire held in the hands and bent back and forth soon becomes very hot and finally breaks at the bend. This is similar to the effect produced on half-inflated tires. The fabric gets hot and soon begins to break. (See Fig. 176.) Rim cuts usually develop after the tire is run a short while without correct inflation. When a tire is rim-cut it is very difficult to make satisfactory repairs.

Bruises are often due to hard driving over rough roads. Even stone chips, pieces of glass, bits of iron or tin cans, and other similar substances inflict cuts on the toughest tread when fairly hit by the tire. If one of these cuts or bruises is neglected, it may cost thousands of tire miles.

Sudden applications of the brakes, causing the wheels to skid, rapidly wears away the rubber tread. This has about the same effect as running with the wheels out of alignment.

When driving on paved roads or streets, the use of chains should be avoided except when necessary. When the car is standing chains should not be left on for a great length of time as the links will injure the treads.

Driving in deep ruts on country roads wears the tire on the side. This part of the tire is not made to withstand wear. The rubbing of the casing against the hard sides of the ruts soon wears away the rubber. Running on street-car tracks also affords many chances of picking up a sliver of iron which finally works its way through the fabric.

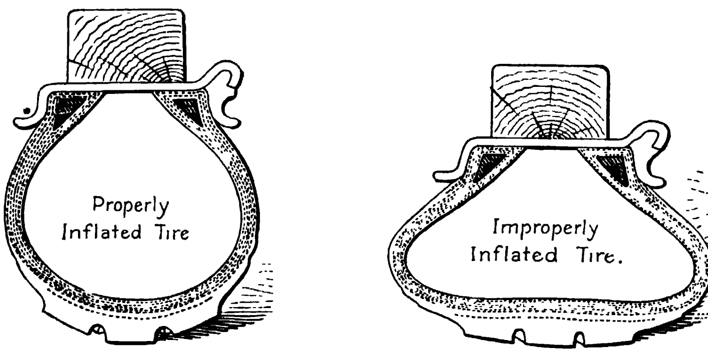


FIG. 176.—Inflating Tires.

Long, continuous fast driving over dry roads in the summer causes the tires to heat up to a point where the fabric gives way and a blow-out results. Under these conditions opportunity should be given for the tires to cool off once in a while, or a slower speed should be maintained.

Owing to the use of purer rubber, to thicker sections, and to better methods of manufacture, the inner tube of to-day is superior to those of several years ago. The repair and preservation of inner tubes is discussed in Job No. 36 of Chapter I.

Tire Suggestions.—If the following suggestions are observed the life of tubes and casings will be prolonged materially:

1. Keep tires properly inflated.
2. Be sure to repair little tread cuts regularly.
3. Prevent blow-outs by avoiding severe jolts and by maintaining full air-pressure.
4. Have blisters cleaned out and repaired at once.
5. Be careful in applying brakes.

6. Avoid sudden stops, quick starts, and skidding.
7. Keep wheels in alignment.
8. Use French talc in the casing, but not too much of it.
9. Avoid ruts and save the side walls.
10. Don't drive on car tracks.
11. Apply chains properly if they must be used; chains always injure tires.
12. Avoid sharp obstructions.
13. Remove grease, oil, and acids from tires at once by using a cloth moistened in gasoline.
14. Examine rims occasionally for irregularities and rust.
15. Prevent damage from rust by using rim paint.
16. Carry spare tubes in a bag.
17. Keep spare tires covered.
18. Be sure that nothing on the machine scrapes the tires as they revolve.
19. Guard against overloading.

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